Sustainable Water Resource and Environmental Management in Developing Countries

By

Dayo Olugboye

BEng(Zaria), MSc, Civil(Ibadan)

A submission presented in partial fulfilment of the requirement of the University of Wolverhampton for the award of degree of Doctor of Philosophy

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Faculty of Science and Engineering
Department Built Environment University
of Wolverhampton

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Declaration

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Abstract

Water supply service delivery has been recognised as a complex challenge facing communities in developing countries. Its particularly serious in sub-Saharan Africa where a significant proportion of the population still lack basic access to safe drinking water supply. Over the years, many externally supported community-managed water facilities have failed to deliver sustainably. This results not only in a loss of financial investment but also constitutes a real threat to people's health and well-being. Therefore, this study aimed to explore options for innovative water service delivery approach that can support vibrant water supply provision as well as provide a guidance framework for sustainable water service delivery in Nigeria.

Due to the socio-technical complexity of the research, the mixed method approach was found to be the most suitable research method after extensive considerations and reviews of other several available research methodologies. The study found that the hand-dug wells (HDW) have enormous potential in sustainable water service delivery to households within the proposed framework arrangement. This research successfully presented a unique model, based on the concept of HDW self-supply, using rope pump technology in conjunction with a community-based water resource management concept.

The proposed approach led to the production of a set of Guidance Frameworks that will aid planning and implementation of a proposed solution. This was validated with key stakeholders and it applicability was rated highly relevant in the water sector. The approach did not only address the question of technical and financial sustainability but also make a case for environmental sustainability. Hence, ensuring that meeting present domestic water needs will not jeopardise the ability of future generations to meet their own needs. Further research was recommended to ensure wider applicability of the model.

Acknowledgement

I wish to express my deep gratitude to my Director of Studies, Dr David Oloke for his understanding, guidance, and supervision throughout this study. I am also very thankful to my supervisor's Dr Nii Ankrah and Professor Akinwale Coker for their immense contributions and unwavering support in shaping this dissertation.

I am indebted to the University of Wolverhampton for the research studentship to undertake this study. Special thanks to all the staff at the School of Science and Engineering and the STAR office who assisted me in one form or the other most especially Mall Sabrina.

I like to express my deep appreciation to my beautiful wife, Mrs Oluwakemi Maneju Olugboye and our son Gabriel Timayin Olugboye, for their love and understanding throughout the period of this research. Special thanks to my Parent and Siblings for their goodwill, prayers and support.

Special thanks to my friend and comrade Engr. Romanus David Irekpita, for believing in me. I will also like to express my gratitude to other friends and family too numerous to mention for their support. Above all, I am grateful to God forgranting me the ability to complete this project.

Dedication

This work is dedicated to many lives of children and women lost due to lack of to poor access to improved drinking water supply and sanitation.

Table of contents

List of papers and publications associated with this thesis.

Book chapter

- Oloke, D., and Olugboye, D. (2014): An overview of management issues in developing a sustainable water supply, sanitation and hygiene (WASH) service delivery in Nigeria. Water Resources for the Built Environment: Managing issues and solution; John Wesley & Sons UK.

Conference papers and proceedings

- Olugboye, D., Oloke D. Ankrah, N. and Coker A.O. (2015*) Exploring potential of Self-Supply in peri-urban area towards sustainable WASH service delivery.* Proceeding of International conference on Sustainable Water Management, Murdoch University, Perth Australia.

- Olugboye, D. and Oloke, D. *(2015) Exploring the potential of community Based water resources management approach towards sustainable WASH service delivery.* Proceedings of international conference on sustainable development, Columbia University New York, USA.

Seminar and workshop presentations

- Olugboye, D. Developing a f*ramework on sustainable WASH service delivery in Nigeria,* presented *at Built Environment and Engineering Research seminars* presentation on 13/02/2013, University of Wolverhampton UK

- Olugboye, D. *Exploring opportunities for sustainable WASH service delivery in developing countries'* University of Wolverhampton Postgraduate Research Seminar Series, presented 03/12/2015. University of Wolverhampton UK.

List of figures

List of tables

List of abbreviations

ADB	Africa Development Bank.
AMCOW	African Ministerial Council on Water
CAPEX	Capital Expenditure
CBO	Community Based Organisations
CBWRM	Community Based Water Resources Management
CDA	Community Development Association
CDC	Centre for Disease Control
DAC	Development Assistance Committee
DFID	Department for International Development
DHS	Demographic Health Surveys
EU	European Union
FCT	Federal Capital Territory
FDG	Focus Group Discussions
FGN	Federal Government of Nigeria
FMoEnv	Federal Ministry of Environment
FMoH	Ministry of Health
FMoWR	Federal Ministry of Water Resources
GLASS	Global Analysis and Assessment of Sanitation and Drinking-Water
HDW	Hand-Dug Well
ICE	The Institution of Civil Engineers
IOM	Institute of Medicine
IYS	International Year of Sanitation
JICA	Japanese International Cooperation Agency
JMP	Joint Monitoring Programme
LGA	Local Government Areas
MDG	Millennium Development Goal
MICS	Multiple Indicator Cluster Surveys
MoE	Ministry of Education
NCWR	National Council on Water Resources
NDHS	Nigerian National Demographic Health Survey

NEPAD	New Partnerships for African Development
NGO	Non-Governmental Organisation
NSDWQ	Nigerian Standard for Drinking Water Quality
NWRI	National Water Resources Institute
NWSSP	National Water Supply and Sanitation Policy
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PPP	Public Private Partnerships
RBDA	River Basin Development Authorities/Boards
RPT	Rope Pump Technology
RUWASSA	Rural Water Supply and Sanitation Agency
RWSN	Rural Water Supply Network
RWSSA	Rural Water Supply and Sanitation Agencies
SDG	Sustainable Development Goal
SMoWR	State Ministries of Water Resources
SS	Self-Supply
SWA	State Water Agencies
UNDP	United Nations Development Project
UN-HABITAT	United Nations Children's Emergency Fund
UNRISD	United Nations Research Institute for Social Development
USAID	United State Agency for International Development
WASH	Water Sanitation and Hygiene
WECD	World Commission on Environment and Development
WES	Water and Environmental Sanitation
WESCOMS	Water and Environmental Sanitation Committees
WHO	World Health Organization
WSP	Water and Sanitation Program,
WSSCC	Water Supply and Sanitation Collaborative Council
WWDR	World Water Development Report

Chapter 1

1.0 Research background

1.1 Introduction

The chapter will discuss the general background of this research on sustainable water service delivery in developing countries. Its highlights will be the statement of the research problems, aim, and objectives. It provides insight on the methodology adopted in undertaking the research, discusses limitations encountered as well as the contribution to knowledge.

1.2 Statement of problem

Achieving sustainability of water services in many developing countries has remained a daunting challenge for stakeholders in the water sector (IRC,2013). In recent years, there has been an increasing amount of knowledge of the proportion of unacceptably high non-functioning water facilities, which has lead to decline in improved water service levels over in some developing countries (Lockwood and Smits, 2011; RWSN, 2010). Despite billions of dollars of aid and government spending in many countries such as Nigeria, studies have shown that one in three rural water supply facilities is not functioning. There average non-functionality rates of between 30 to 40% globally and as high as 67% for handpumps in sub-Saharan Africa (RWSN, 2009).

Moriarty et al, (2010) noted that in the last three to four decades, substantial amounts of resources have been invested to provide water supply services in sub-Saharan Africa countries,

however, most of these services have been largely unsustainable. According to (Harvey, 2009) many of the water supply programmes which started with the support of international agencies in developing countries have failed to deliver their expected outcome over time. The long-term sustainability of water service delivery has been a complex and persistent challenge facing communities, governments, and international development agencies. A significant proportion of communities already provided with water facilities can experience major failings in access to improved water sources within a few short years. These failings result in not only a loss of financial investment and community aspiration but also a very real threat to human health and wellbeing (Lockwood, 2014).

A major challenge facing the development community among other issues are the difficulties that exist with the provision, and management of sustainable water supply services in many developing countries (UNRISD, 2007). According to (WaterAid, 2011) 'If communities slip back into a situation where they have to rely on unimproved water supply services at any time after facilities have been provided then investment has effectively been wasted'. From the foregoing, it is clear that there are challenges to sustainable water delivery and the key to sustainable services would appear to be a need to identify what enables water supply services to remain operational overtime.

According to Mathew (2004), sustained beneficial outcomes from water supply interventions are still for many people and their governments, an elusive goal. Therefore, enhancing progress in drinking water supply coverage depends on a greater focus on the sustainability of investments and service delivery outcomes rather than just installing water supply facilities. Several strategies and approaches, have evolved in a bid to ensure water services continue to sustainably deliver benefits to users over time. In many rural communities in Nigeria the

problem of abandoned borehole due to the inability or lack of willing to pay or contribute towards operation and maintenance has been recognised as a major challenge (Oloke and Olugboye, 2014). This requires new tools, approaches, and collaborative learning between implementers, donors and beneficiaries. Achieving sustainable water services delivery will require greater knowledge and understanding of an alternatives approach based on sustainability drivers and how they are inter-related is important.

1.3 Research aim

The research aim is to explore sustainable water service delivery option in rural Nigeria. This research sought to contribute to an understanding of how water supply projects systems can continue to deliver functionally over time, through exploring and the development sustainable options and thus develop a proposed guidance framework.

1.4 Research objectives

To address the aim and the research questions posed by this study, the following research objectives were to:

1. Conduct a review of global drinking water development, trends and coverage;
2. Critically review sustainable water service delivery concepts;
3. Undertake review of the current state of water service delivery in Nigeria;
4. Conduct an exploratory study on sustainable water service delivery aim at alternative solutions;
5. Establish an appropriate research methodology, fieldwork and data gathering tools;

6. Analyse the field data gathered to gain insight into the current challenges and opportunities to aid development of a sustainable water service delivery guideline framework;

7. Validate the technical effectiveness and usefulness of the guidance framework from stakeholder's perspectives.

1.5 Research methodology

Mixed method approach was adopted for the study. It was considered the most appropriate suitable because of the research span through social and technical subject areas covered in the study. The mixed method comprises of quantitative and qualitative techniques. Quantitative techniques include water facilities inventory surveys, household respondents survey, sanitary risk assessment survey, water quality testing and perception surveys.

Qualitative methods include direct observation, key informant interview, and discussions. Data were obtained from water facilities inventory survey aimed at determining the functionality level of conventional water facilities such as handpumps this was with a view to compare findings with the reported level of services breakdown in literature. Household surveys were administered to 96 individuals to represent the social demographic of the area. Water quality and sanitary risk assessment survey were conducted on 50 HDW and 10 handpump boreholes.

An exploratory review on viable service delivery options with an emphasis on technical, financial and environmental sustainability was also undertaken. This informed perception surveys conducted to understand user perspective on the concepts of Self-Supply handdug well, rope pump technology and community-based water resources management using Likert scale.

Data collected were analysed using descriptive statistics that provided useful information towards development of a guidance framework presented in chapter 8.

1.6 Thesis outline and structure

Chapter 1: Background to research.

The chapter presents a general overview of the thesis outline, it presents the research statement, aim and objectives. It highlights the research contribution to knowledge, and set out the thesis structure linking the study objectives, methodology and the chapters are discussed.

Chapter 2: A review of drinking water development, trends and coverage in developing countries.

This chapter presents a literature review of drinking water development, trends and coverage in developing countries. It highlights progress and development made in the water sector. Its presented the recent global trends and coverage, and discusses importance of improved access to drinking water with a special focus on sub-Saharan Africa are discussed.

Chapter 3: Exploring sustainable water service delivery concepts

This chapter presents the general idea of sustainability and sustainable development concept, and how they are linked to sustainable water service delivery. Three main service delivery approaches are noted as: externally driven, enterprise driven (private sector), and self-supply initiatives. While externally driven approach has been associated with service failures in many communities across Africa, enterprise driven private sector has a peculiar challenge with demand and supply while self-supply promotes user initiative, ownership and responsibility are discussed.

Chapter 4: A critical review of Nigeria drinking water supply coverage

The chapter presents a literature review of Nigeria drinking water supply sector. It presented a general background on Nigeria. Its discusses population growth and economy in relation to water supply. It highlights three-fundamental drinking water supply system in urban, small town and rural. Finally, it explores the challenges with unsustainable water supply in Nigeria to show why sustainable services are important in Nigeria are discussed.

Chapter 5: Exploring alternative approach towards sustainable water service delivery in Nigeria

The chapter presented literature reviews on an alternative option to the rural water supply based on technical and financial sustainability in addition to sustainable water resources management from an environmental sustainability perspective. The review explores self-supply Handdug well (HDW) using the rope pump technology and Community Base Water Resource Management approach as a potential solution to unsustainable rural water service delivery are discussed.

Chapter 6: Research methodology

This chapter presents the review of the research methodologies and the adopted research method and the justification for the approach used. Due to the socio-technical approach to the research, a mixed approach is proposed and justified. Qualitative and quantitative collection strategies involving questionnaires survey, interviews and direct observation are discussed.

Chapter 7: Field investigations, discussions and findings

The chapter presented the result, findings and discussions from water facility inventory survey, household respondent questionnaires, sanitary risk assessment survey, water quality test, direct observation, perception surveys and validation questionnaires are discussed.

Chapter 8: Sustainable water service delivery guidance framework development and validation

This chapter presented the Sustainable Rural Water Supply Service Delivery (SRUWASSD) guidance framework. The framework provides guidance on each of the sustainability factor identified in the literature. The framework designed to allow end users and practitioners to apply the guidance on any of the sustainability factor lacking towards order to achieving desired sustained water services. It also discussed the outcome of stakeholder validation of the approach.

Chapter 9: Recommendations and conclusion

The chapter presented an overview of the research, discussion which links to achieving research objectives, contributions to knowledge, limitation of the research recommendations suggestions for future work and conclusion.

Figure 1.1 shows the thesis outline, linking the research aim and objectives with chapters and methodology used. Overall, the entire research process can be group into three stages which include stage 1 consisting of chapter 2-5 (Literature review), stage 2 consisting of (Exploratory studies, field investigation, data collection and data analysis) and stage 3 which consisting of (development and validation of the guidance framework, recommendation and conclusion)

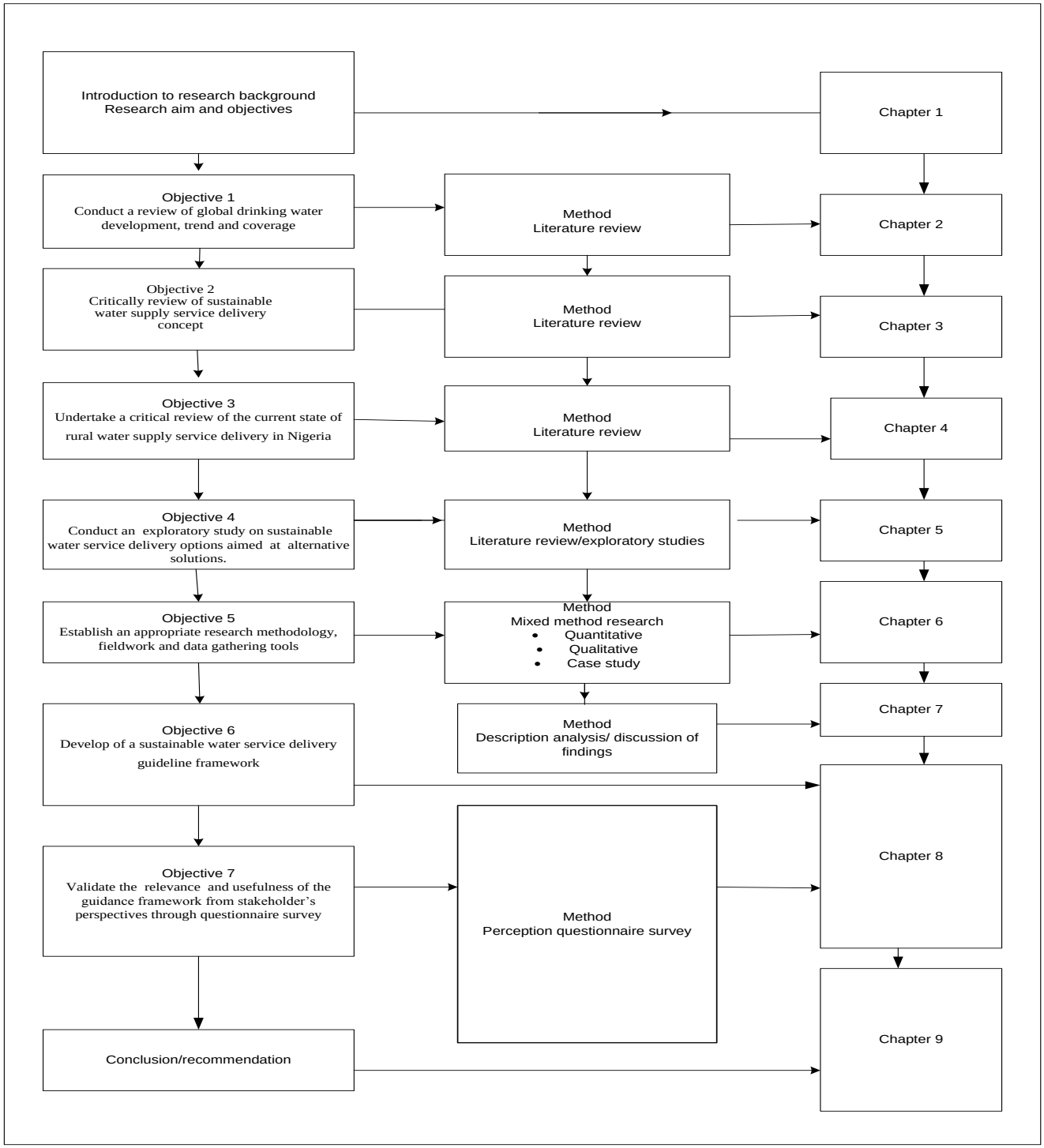

Figure 1.1: Inter- connections between the research objectives, methods and chapters of the thesis.

1.7 Contribution to knowledge

The research amongst other finds presented a Sustainable Rural Water Supply Service Delivery (SRUWASSD) guidance framework that could provide practitioners, policymakers and other stakeholders in Nigerian water sector, a viable tool towards planning, designing and implantation of rural water services sustainably. It will also contribute to literature in the knowledge of sustainable water supply in developing countries. It is envisaged to also promotes opportunities for further research in this subject area.

1.8 Research dissemination

The dissemination of research progress was through poster presentations, paper publications, a book chapter, and reports at conferences, seminars, online journals and webinars (See page xiii)

1.9 Chapter summary

Chapter one presented the general background and rationale behind the research. It presented an overview of the study aim and objectives, research questions, methodology and the philosophical context of the research as well as the benefits to derive from the research. It also highlighted challenges encountered toward achieving the research goals.

The thesis structure was therefore outlined to give an overview of the entire study undertaken and the description of the work done to achieve the goal of the research. The thesis present reviews, arguments, concepts and creative ideas arising from the investigation in the subject area discussed throughout the thesis in detail in the subsequent chapters.

Chapter 2

Drinking water development, trends and coverage in developing countries

2.1 Introduction

This chapter aims to provide background on global water resource, drinking water supply development, trends and coverage. Provide a basic understanding of common terminologies and conventions used in water supply sector. Explore the importance of improved access to water in developing countries. Highlights some of the milestones in global water development agenda. It will also seek to identify stakeholders in the water sector as well as their roles and responsibilities, highlight water supply finance mechanism and seek to discuss of barriers to increasing drinking water access coverage as well as the challenges with the construction, operations and maintenance of existing facilities, in sub-Sahara Africa.

2.2 Global water resource

Water is one of the world's most valuable resources. It is a necessity of life for both plants and animals. As shown in Figure 2.1, the earth is made of 97% saline water, contain in the ocean and 3% freshwater. The freshwater has 68.7% lock up in icebergs and glaciers, 30.1 % is stored in groundwater, 0.3% available as surface water and 0.9% others. Surface water is found as 87% lakes and 11% swamps and 2% rivers (Shiklomanov,1993).

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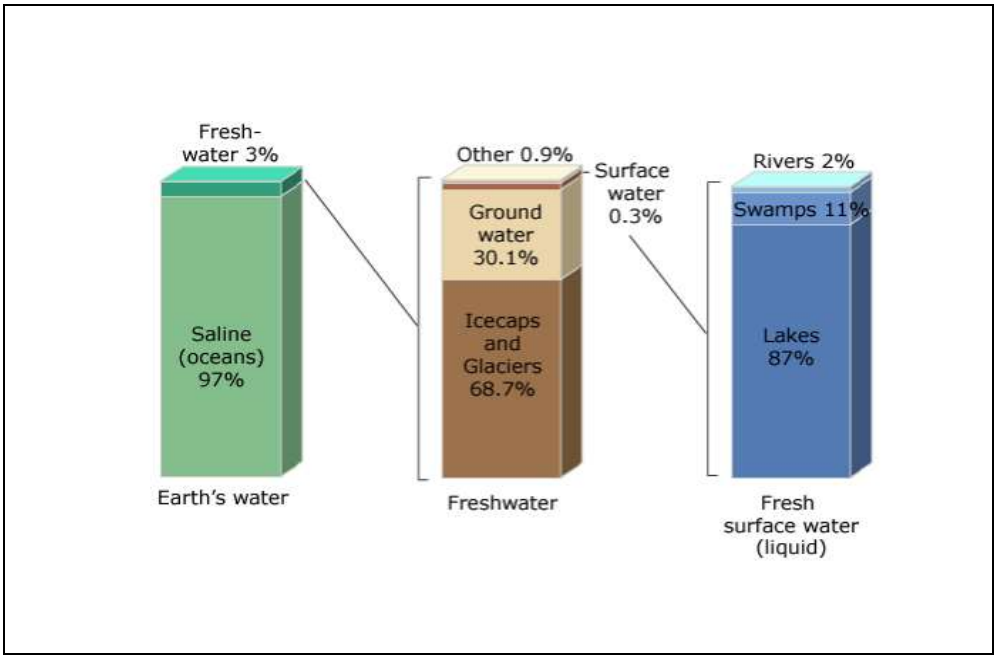


Figure 2.1: Distribution of earth water resources (Source: Gleick, 1996)

2.3 Global freshwater demand

According to UN-Water (2016), globally 70% freshwater sources are used for agriculture, 20% or industrial processes, and only 10% on domestic uses. Water crisis is considered as a foremost global risk based on impact to society as a measure of devastation (World Economic Forum, 2015). However freshwater withdrawals have increased globally by about 1% per year since the 1980s, mainly due to growing demand in developing countries (Gleik,2000).

According to (UN DESA, 2011), it is projected that populations living in urban areas will almost double, from 3.6 billion in 2011 to 6.3 billion in 2050. Also, it is expected that between 2011 and 2050, the world population is would increase by 33%, that is growing from 7 billion to 9.3 billion people on the earth. This development will result in increasing demand on global freshwater resources. Therefore, beyond the need to meet the world's growing population drinking water supply, there is the need to ensure that these needs are met sustainably.

2.4 Milestones in global water supply development agenda

Over the last five decades, concerted effort has been made on increasing global water supply coverage. Stakeholders in the water sector at states, regional and global level have developed policy, built institutional structures to achieve universal coverage. These effort are evident in the various declarations, resolutions and policies developed at national, regional and international level supporting improved access to safe drinking water around the world. While tremendous progress has been achieved globally, there are concerns on sustainability of facilities provided, particularly in developing countries. Table 2.1 and Box 2.1 contain summaries of global milestone on drinking water supply and water resource management development.

Table 2.1 Milestone on drinking water supply and water resource management.

Dates	Milestone events	Outcomes
1972	• UN Conference on the Human Environment, Stockholm	• Declaration of the UN Conference on the Human Environment
1977	• UN Conference on Water, Mar del Plata	• Mar del Plata Action Plan (MPAP)
1981 - 1990 International Drinking Water and Sanitation Decade		
1990	• Global Consultation on Safe Water and Sanitation for the 1990's, New Delhi • World Summit for Children, New York	• New Delhi Statement: • Declaration on the Survival, Protection and Development of Children
1992	• International Conference on Water and the Environment, Dublin • UN Conference on environment and Development (UNCED Earth Summit), Rio de Janeiro	• Dublin Statement on Water and Sustainable Development • Rio Declaration on Environment and Development • Agenda 21

1994	• Ministerial Conference on Drinking Water Supply and Environmental Sanitation, Noordwijk • UN International Conference on Population and Development, Cairo	• Action Programme • Programme of Action
1995	• World Summit for Social Development, Copenhagen • UN Fourth World Conference on Women, Beijing	• Copenhagen Declaration on the Social Development • Beijing Declaration and Platform for Action
1996	• UN Conference on Human Settlements (Habitat II), Istanbul	• The Habitat Agenda • Rome Declaration on World Food Security
1997	• 1st World Water Forum, Marrakech	• UN Millennium Declaration • Marrakech Declaration
2000	• 2nd World Water Forum, The Hague	• World Water Vision: Making Water Everybody's Business • Ministerial Declaration on Water Security in the 21st Century
2001	• International Conference on Freshwater, Bonn	• Ministerial Declaration
2002	• World Summit on Sustainable development, Rio+10, Johannesburg	• Plan of Implementation
2003	• 3rd World Water Forum, Japan • International Year of Freshwater	
2006	• 4th World Water Forum, Mexico	• Ministerial Declaration, Water for growth and development, Implementing Integrated Water Resources Management (IWRM). • 2nd edition of the United Nations World Water Development Report

Box 2.1 Notable water, sanitation and hygiene milestones 2010-2015

- Sanitation and Water for All Inaugural High Level Meeting 2010
- Declarations on the Human Right to Water and Sanitation by United Nations General, 2010 Assembly and Human Rights Council, 2010
- MDG Review Summit, 2010
- First International Consultation on WASH post-2015 – Berlin, 2011
- Second International Consultation on WASH post-2015 – The Hague, 2012
- United Nations Deputy Secretary- General Call to Action on Sanitation 2004
- United Nations thematic consultation on Water and Sanitation 2013
- Pen Working Group on SDG report,2014
- Third International Conference on Financing for Development,2015
- United Nations Declaration on Sustainable Development, 2015

(Source: WHO and UNICEF, 2015)

At all level, stakeholders have continuously assessed and review progress made and investment required to achieve universal coverage. For example, water supply coverage was a target under MDG Goal 7, which was to '*halve the proportion of the universal population without sustainable access to clean and safe drinking water and basic sanitation by 2015'*, but is now one of the central core of the global Sustainable Development Goals (SDGs) development

agenda because of the critical role water supply in global development agenda. Goal 6 of the SDG's is stated as Sustainable Management of Water and Sanitation for All with the following targets:

- By 2030, achieve universal and equitable access to safe and affordable drinking water for all
- By 2030, achieve access to adequate and equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
- By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and increasing recycling and safe reuse globally
- By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity
- By 2030 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- By 2030, expand international cooperation and capacity-building support to developing countries in water and sanitation related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies. (Minas et al 2015)

The SDGs re-affirmed commitment at all level, and the sense of importance and urgency and of water resources and water supply to global development agenda. However, all of the above progress, commitment and investment could be jeopardised due to widespread record of service

failures in many developing countries including Nigeria. A better understanding of how water services could be delivered sustainably is a key knowledge gap requiring in-depth interrogation.

2.5 Stakeholders in water sector

Typically, water supply services are provided by the following stakeholders, including;

- Government agencies
- Public and private utilities
- Small independent providers (formal and informal)
- NGOs and community-based organizations;
- Communities and Households

2.6 Financing water supply

According to Trémolet and Rama (2012), financing water supply varies greatly from one country to another, depending on factors such as water resource availability, historical legacy, official coverage of water services or the extent to which services are decentralized. GLAAS (2014) in a broader concept noted that water financing has being generally divided into public and non-public sector funds (See Table 2.2). Figure 2.2 illustrates a water service delivery finance flow and investment pattern. A detailed review of the Nigeria water sector profile will be discussed extensively in chapter 3.

Table 2.2 Water supply funding mechanism
(Source: OECD, 2015)

Public sector financing agents	Non-public sector financing agents
• National authorities • Regional authorities • Local authorities • Public • Regulators	• Bilateral and multilateral donors • Private providers • NGOs • Community-based organizations • Households

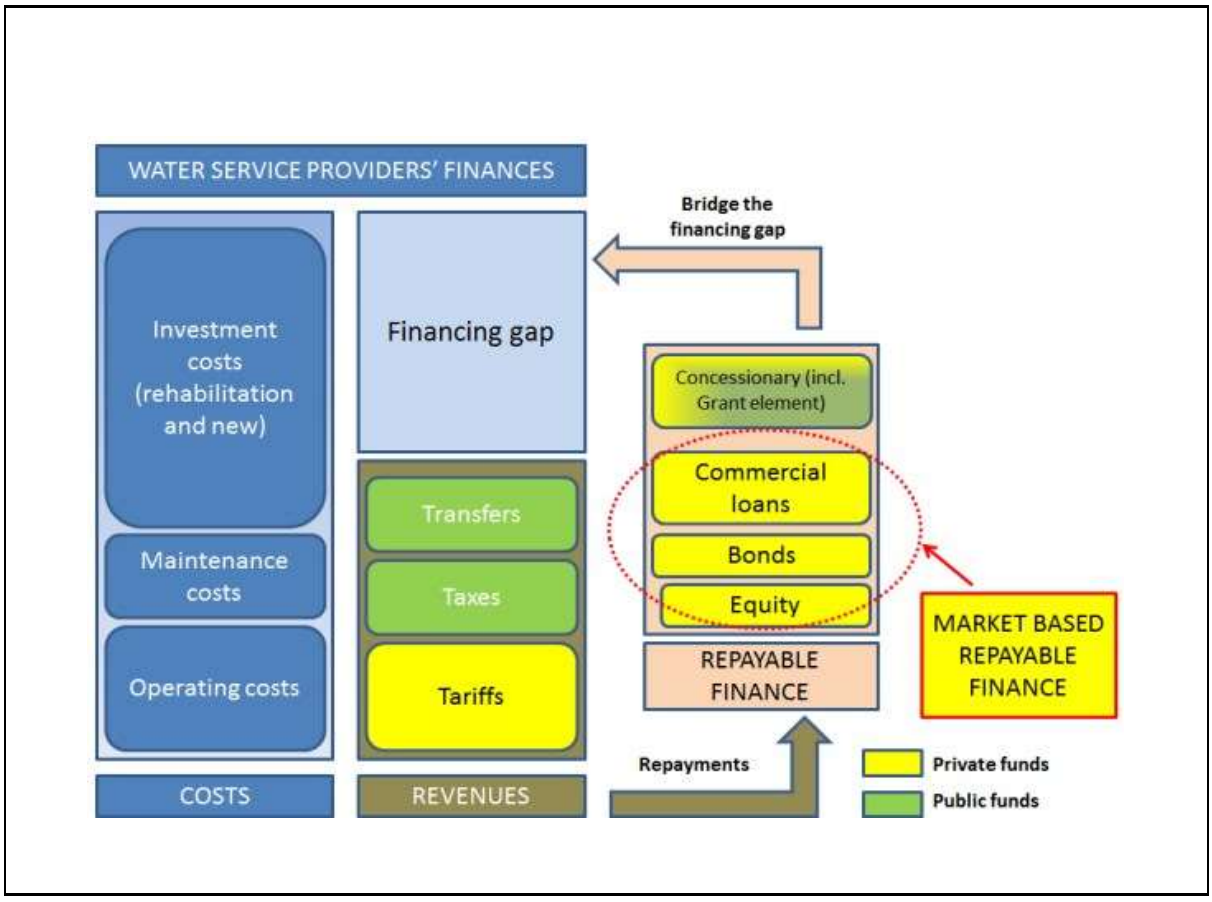


Figure 2.2: Sources of finance for the water sector
(Source: Trémolet and Rama 2012)

In many developing countries, over the last decade substantial amount of the water finance come from External Support Agencies (see section 4.4.9). Figure 2.3 shows the graph of external aid to water and sanitation between 1973-2013 (OECD,2015). However, due to poor operation and maintenance, these investments often fail to achieve significant impacts in all these aspects, and facilities are often under-utilised, broken down, or abandoned, (Carter et al, 1999).

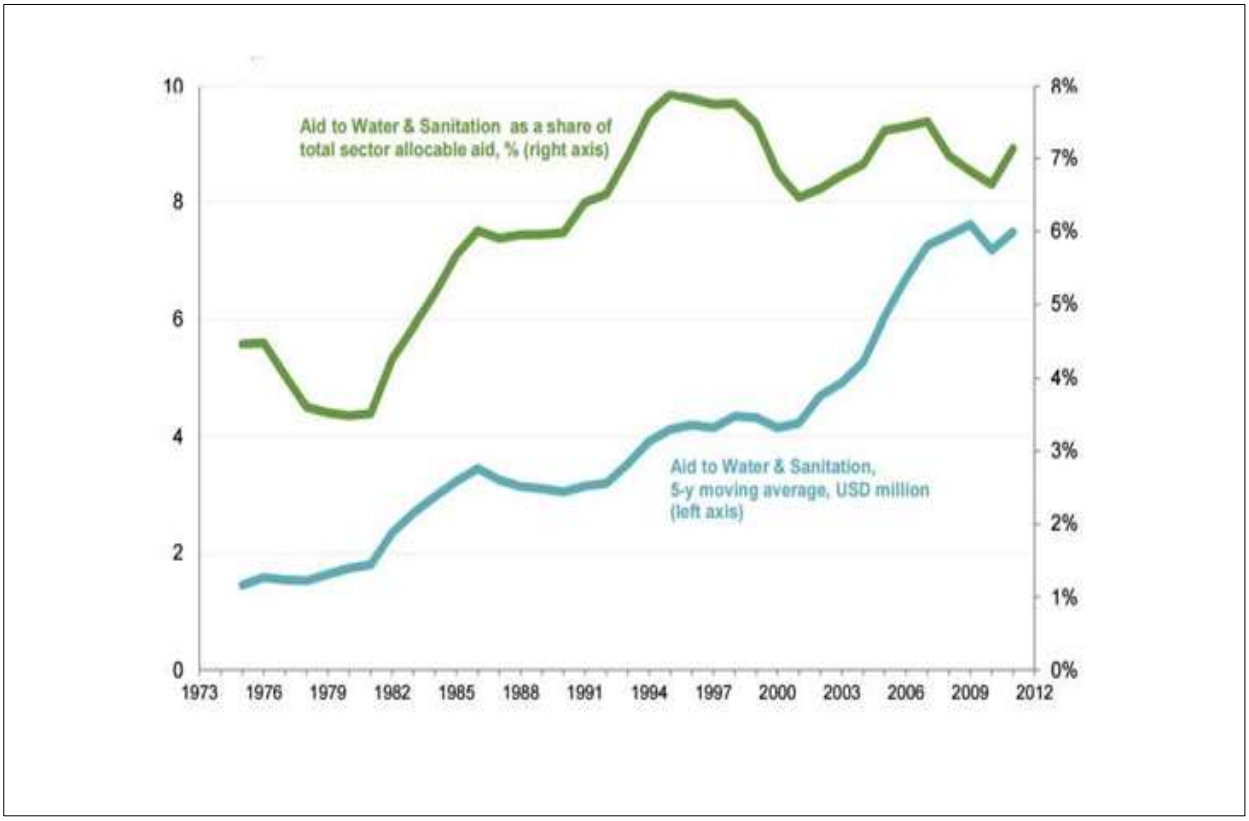


Figure 2.3: External Aid to WASH between 1973- 2013
(Source: OECD, 2015)

2.7 Global drinking water supply coverage 1990-2015.

According to JMP (2015), in 139 countries, more than 90% of the population use improved drinking water sources. Globally, it is only in 3 countries, that less than 50% of the population use improved drinking water sources as at 2015 compared to 23% in 1990. 91% of the world population now use improved drinking water sources. The number of the global population using surface water has decreased from 346 -159 million people. Over the period 2.6 billion people have gained access to an improved drinking water source.

Globally, the number of countries with less than 50% coverage in improved drinking water has decreased from 23 to 3. It is estimated that 663 million people worldwide still use unimproved drinking water sources. This includes people using unprotected wells and springs and surface water, most whom are in Asia and sub-Saharan Africa. In Figure 2.4, the orange colour represents countries in which less than 50% of the population uses unimproved drinking water sources. About half of all people using unimproved drinking water sources live in sub-Saharan Africa.

Table 2.3 contains the summary of progress made globally between 1990 and 2015. The Table contain proportion of the population using improved drinking water sources, in rural and urban settlements as well as the number of people still lacking access to improved water supply.

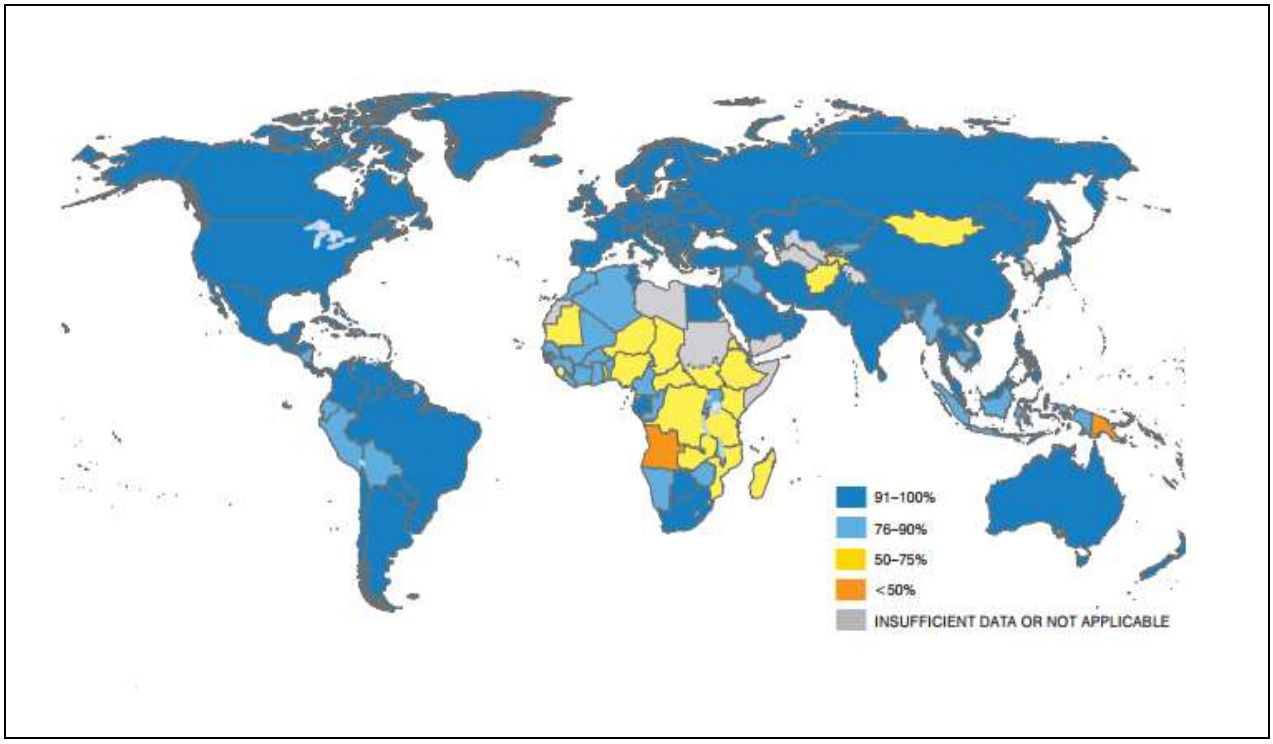


Figure 2.4: Proportion of the population using improved drinking water sources (Source: MP, 2015)

Table 2.3 Global water supply coverage between 1990 - 2015 (Source: WHO and UNICEF 2015)

1990	2015
• Global population 5.3 billion	• Global population 7.3 billion
• 57% of the global population rural	• 54% of the global population urban
• 76% of the population used improved drinking water sources	• 91% of the population use improved drinking water sources
• 1.3 billion people lacked improved drinking water sources	• 663 million people lack improved drinking water sources
• 346 million people used surface water	• 159 million people use surface water
• In 87 countries, more than 90% of the population used improved drinking water sources	• In 139 countries, more than 90% of the population use improved drinking water sources
• In 23 countries, less than 50% of the population used improved drinking water sources	• In 3 countries, less than 50% of the population use improved drinking water sources

2.8 Importance of drinking water supply

Universal access to safe drinking water supply is a long-standing development goal and the linkages between improvements in drinking water supply and the achievement of targets relating to poverty, health, nutrition, education, gender equality sanitation and hygiene and sustainable economic growth are well established (United Nation, 2014). Section 2.7.1-2.7.5 discuss in detail the impact of improved water supply on general wellbeing and improve standard of living.

2.8.1 Health benefits

Many developing countries, as much as 80% of illnesses are linked to poor water and sanitation conditions (UN, 2003). It is estimated that half of the world's hospital beds are filled with people suffering from a water-related disease, (UNEP/UN-HABITAT, 2009). Adequate access to good water facility has been strongly linked to considerable reductions in acute respiratory infections and reduced infant mortality (Jefferson et al., 2009, Luby et al., 2005, Rhee et al., 2008). Cairncross and Valdmanis (2006) established that the spread of water- borne diseases can be contained by improved sanitation and hygiene. Practices, such as hand washing, sanitation, water treatment and safe drinking water storage have each been proven to reduce diarrhoea rates by 30–40% (Curtis & Cairncross, 2003; Fewtrell et al., 2005; Clasen et al., 2007).

Figure 2.5 describe how provision of safe water supply can improve hygiene and sanitation can serve as a barrier to minimising the probability of disease and infections. Access to a safe water supply for drinking, cooking, and personal hygiene is an essential prerequisite for health, an

inadequate water supply whether as a result of poor access or quality, low reliability, high cost, or difficulty of management is associated with significant health risks (Hunter, 2010)

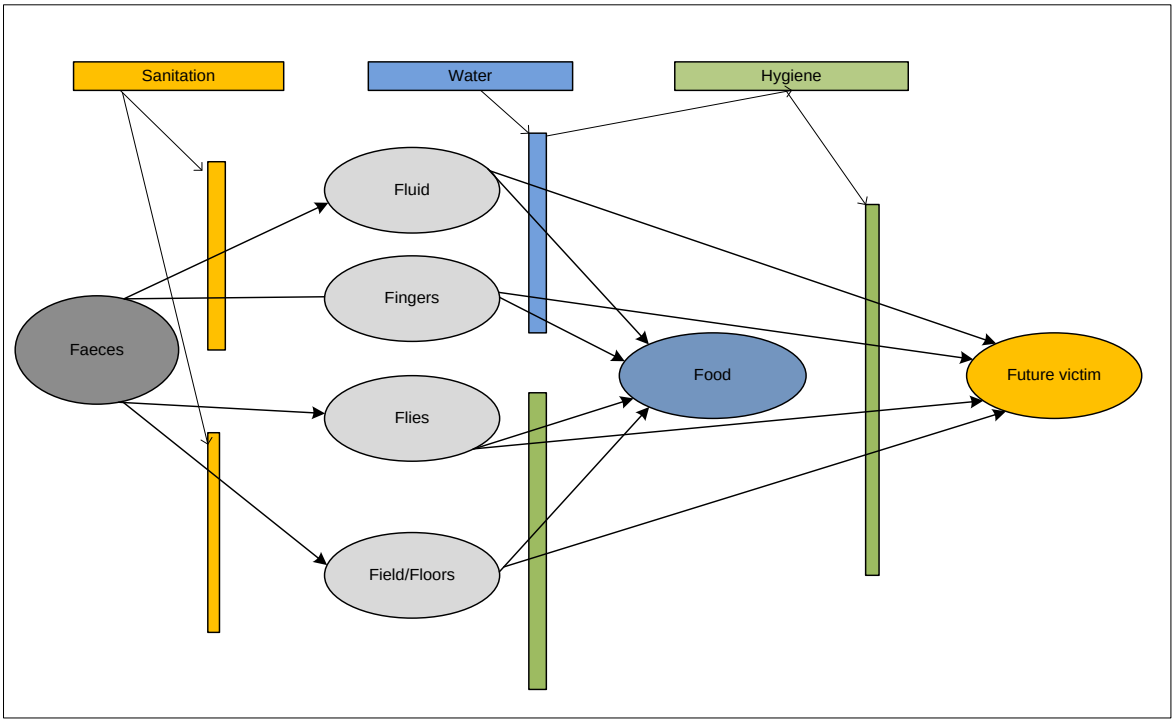


Figure 2.5: Faecal oral transmission route
(Source: World Bank,2005)

WHO (2014) noted that millions of children have been saved from premature death and illness related to malnutrition and preventable water-borne diseases resulting in a reduction in incidences of diarrhoea, better maternal health, care for new-borns and that adults in general now live longer and have healthier lives.

Nearly 1 out of every 5 deaths under the age of 5 worldwide is due to a water-related disease, (WHO/UNICEF,2009). Child mortality is considered higher amongst households with poor access to clean water and sanitation facilities (UNDP, 2010). It is generally accepted that lack of potable water and basic sanitation services remains one of the world's most urgent health issues (Onesmo and Holmes, 2006). However, where water facilities have been provided to

ensure households and communities are protected from ill health, the frequent breakdown could threaten this goal, (Gleik, 2002).

In a similar study (Whiteman, 2013) studied data on 9,469 children under 18 years of age and analysed the effect of water, sanitation and hygiene programs on their physical growth, found a 0.5cm increased height growth in children under the age of five when water quality and access were improved in the household alongside access to soap. Figure 2.6 depicts progress made towards reversing under-five infant mortality rate expressed in deaths per 1,000 live births across the world regions between 1990 and 2013 (UNICEF 2014).

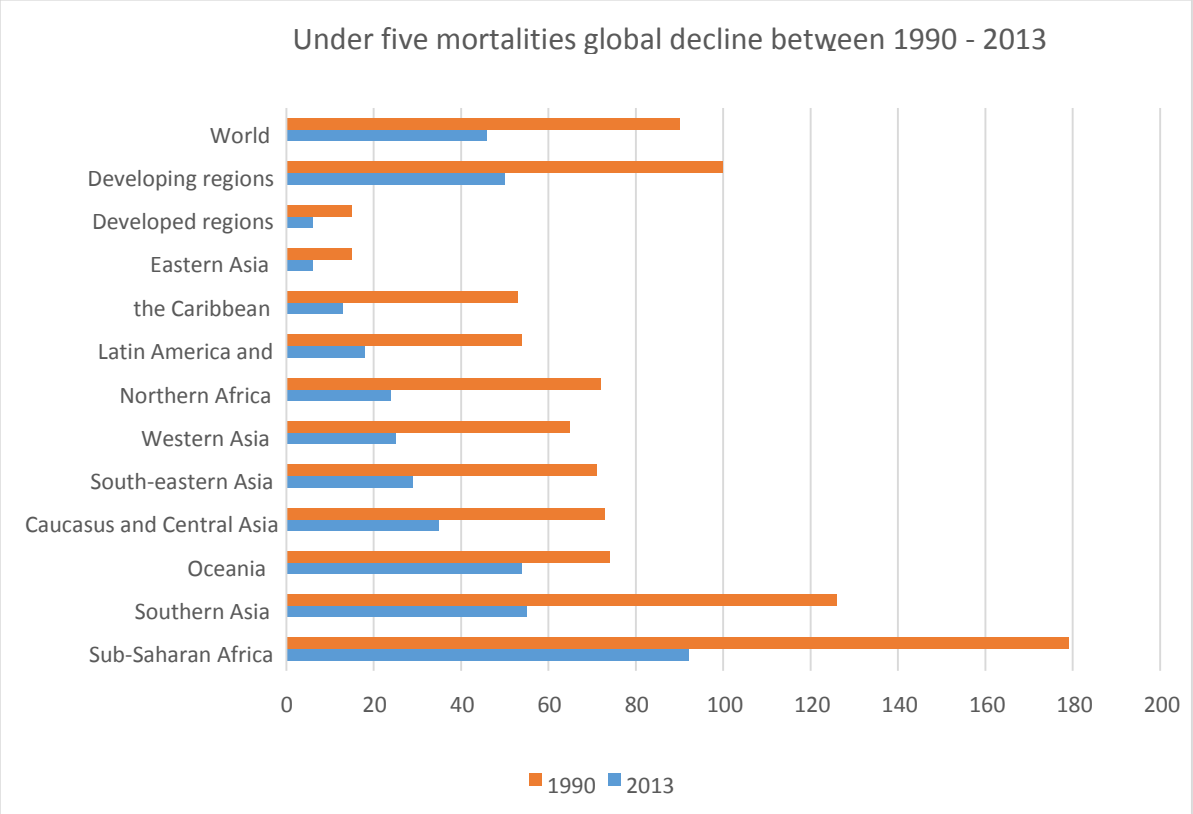


Figure 2.6: Under-five mortality declined in all regions between 1990 and 2013 (Source: UNICEF et al, 2014)

The figure shows that globally there has been progress in overcoming infant mortality in over 23 years. For example, there were about 100 deaths per 1000 live birth as at 1990 but has reduced to less than 50 deaths per 1000 per live births in 2013. The sharp decline in infant death, especially in the sub-Saharan Africa could be attributed to a very large extent, to more than two decades of concerted effort by stakeholders in investment towards improving water supply in the region by different stakeholders.

2.8.2 Improved general wellbeing

Barbara (2014) affirmed that very few interventions would have a greater impact on the lives of the world's poorest and most marginalised people than reducing the time spent collecting water and addressing the health problems caused by poor water supply, sanitation and hygiene. The UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) report, indicated that discomfort caused by a lack of adequate water and sanitation could lead to poor self-esteem and a feeling of hopelessness among women (GLAAS, 2014).

The time saved by children, particularly girl, searching for water and distance covered in the bush or unsafe places to defecate can lead to improved school attendance and may result in higher percentage of school completion for girls. 443 million school days are lost each year due to water-related diseases (UNDP, 2006). Access to water facilities will mean fewer days lost in the home, at school or work due to prevented sickness, greater comfort, privacy and safety especially true for women, children, the elderly and people living with disabilities, which enhances a greater sense of dignity and general wellbeing (WaterAid, 2014).

2.8.3 Economic benefits

The WHO estimates the total global economic loss per annum resulting from poor water supply and sanitation at 260 billion US Dollars. It is estimated an overall gain of 1.5% of global Gross Domestic Product(GDP) and a $4.3 return is expected for every $1 invested in water supply, sanitation and hygiene-related services, (WHO, 2012; Fogden and Wood, 2009) suggested that the economies of the fastest-growing regions in the world, and other emerging markets, are likely to be the first to suffer in a situation of a sharp fall in access to water facilities.

Carter and Bevan (2008) and Hanjra and Gichuki (2008) argued that investments in improved water supply access alleviate poverty. Water plays a pivotal role in society; it is critical for economic development, for human health and social welfare, especially for the poor, and for environmental sustainability (Braune and Xu, 2010). Figure 2.7 is an illustrates the relationship between improved access to water supply and poverty reduction for households and communities in developing countries.

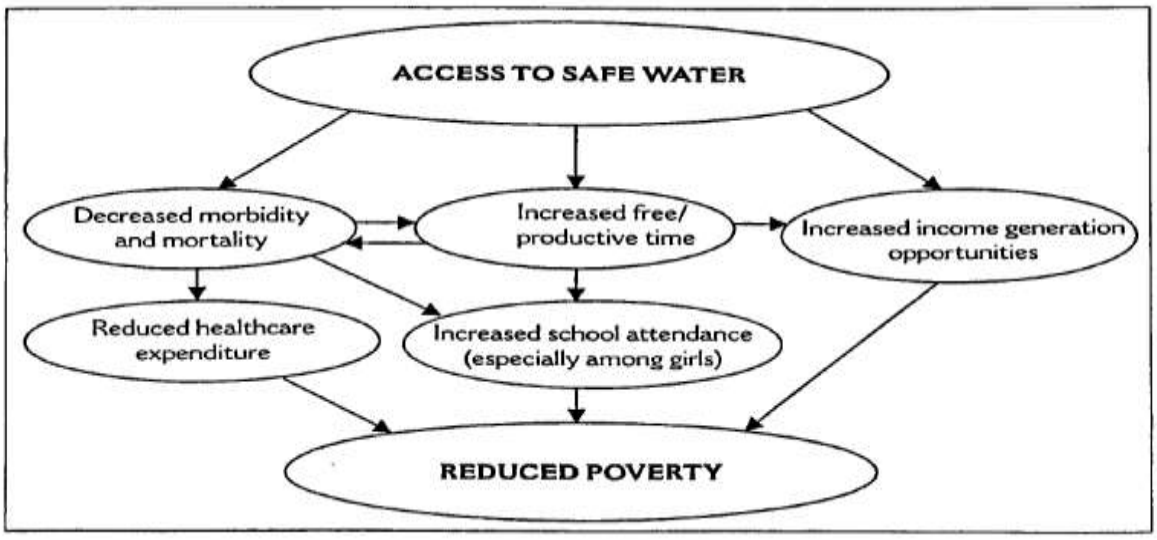


Figure 2.7: Relationship between access to water supply and poverty (Source Adapted from Harvey 2009)

According to Fogden and Wood (2009), globalisation and interdependence among the world's economies mean that a growth crisis in one region could have a subsequent effect on the developed world, and also stated that economic growth seems to be dependent on high levels of access to water facilities; a decline in access to facilities such as safe drinking water is expected to result in following:

- A higher disease burdens
- Lower education levels
- Lower worker productivity
- Higher labour costs
- Slower economic growth

The Institute of Medicine (IOM, 2009) pointed out that whilst poverty has been a major barrier to gaining access to clean drinking water and sanitation in many parts of the developing world, access to and the availability of clean water is a prerequisite to sustainable growth and development of communities around the world. Hunter et al. (2010) argued that there is a strong relationship between improved water supply and livelihoods, whether for productive or domestic uses. Water facilities play a major role in laying the foundation for economic growth, by increasing the assurance of supply as well as by improving water quality and therefore human health (Phillips et al., 2006). Therefore, unsustainable water service delivery could lock people perpetually in the cycle of poverty.

2.8.4 Environmental benefits

Campbell et al, (2014) submitted that water supply interventions have been shown to be highly effective in reducing the environmental exposure to diseases. Figure 2.8 demonstrates how improved water supply and sanitation can impact on achieving environmental sustainability. According to Pickford (1991), poor environmental conditions arising from the unhygienic disposal of excreta and sullage, and accumulation of solid wastes, contributes to the spread of disease. This suggests that a water supply facility should not only serve the people but designed such that it is environmentally sustainable.

Reed and Shaw (2008) claimed proper provision of water and sanitation facilities will bring about an immediate benefit to the environment such as noticeable visual improvement, reduction in foul odour and flies, and the improvements to the quality of surface water from a reduction of excreta polluting local water courses.

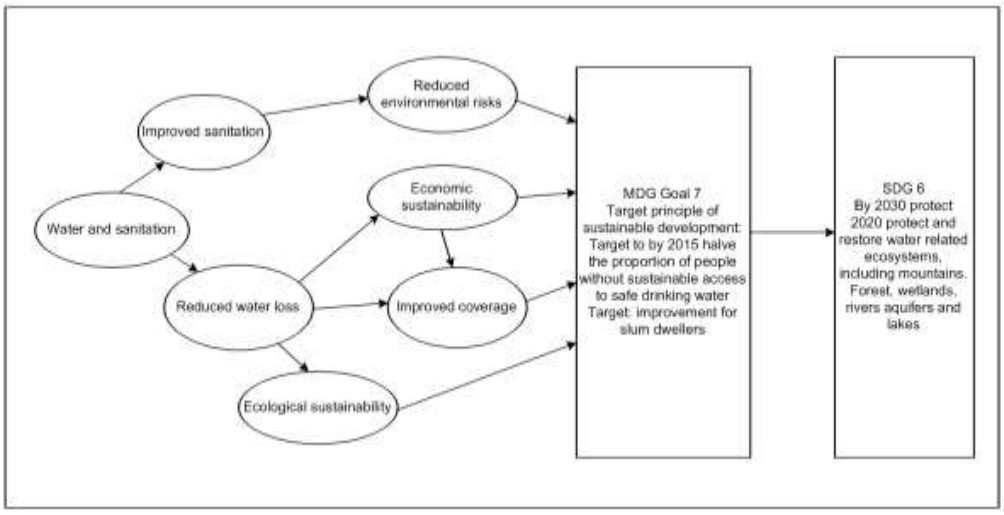


Figure 2.8 Impact of improved water on environmental sustainability (Source: Adapted from Hesselbarth, 2005)

2.8.5 Reduce gender burden on women and girls

According to (WHO/UNICEF, 2010), Girls under the age of 15 are twice as likely as boys to be the family member responsible for fetching water. Almost two-thirds, 64% of households rely on women to get the family's water when there is no water source in the home. The study also found that physical and time burden of water hauling was found to fall primarily on women and girls who make up 72% of those tasked with fetching water. Women and girls are responsible for water collection in seven out of ten households in 45 developing countries, (WHO/UNICEF, 2015). An improved and sustainable access to water facility within a community could reduce the burden on women and girls. Figure 2.9 and 2.10 shows majority of those collecting water as women and girls.

Although, improved water access has great importance and is generally agreed that investment in water services can, and does, deliver results, however the questions remain on how good is 'improved access'? How safe is the water? How long does it take users to collect water? How affordable and reliable is the service? How sustainable are the water resources? These questions expose a knowledge gap that need further interrogation (RWSN, 2015); This research will focus on among other questions on the sustainability of water resources and water service delivery facilities in rural communities.

Figure 2.9: Girls collecting water from a water kiosk

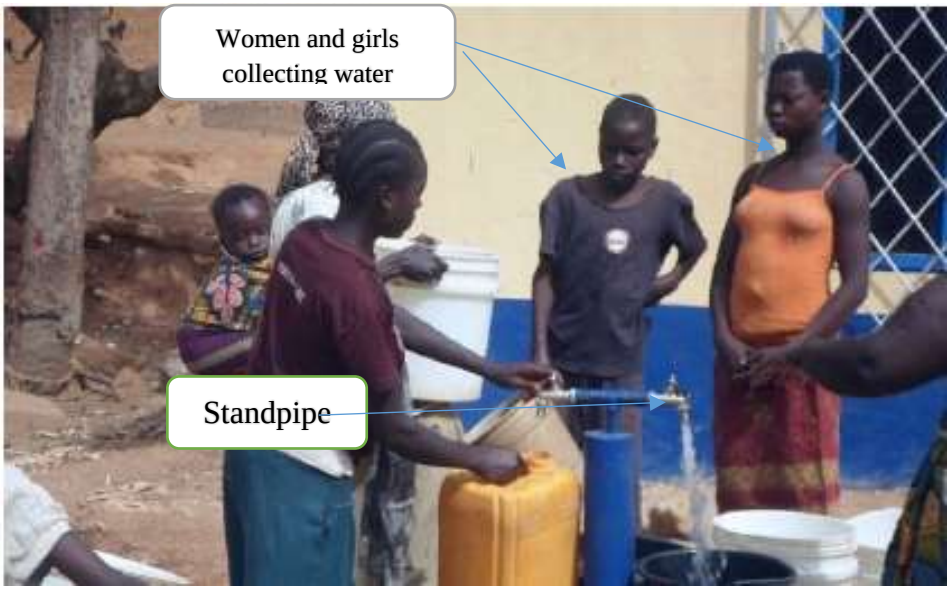


Figure 2.10: Girls collecting water from a standpipe

2.9 Impediments to global progress in water service delivery

According to the United Nations special rapporteur on the human right to safe drinking water and sanitation (Heller, 2014), common barriers to safe access to water supply, improved sanitation and hygiene worldwide accordingly include:

Legal: There are frequently legal barriers for people who, for example, do not have documents proving they have the right to live where they are living. People who live in 'informal' settlements are often directly or indirectly excluded from provision because they do not have security of tenure.

Institutional: Institutional responsibilities are often fragmented and poorly coordinated. This results in inconsistencies and contradictions in service provision and makes it difficult for people to know where to turn for help.

Administrative: Complicated administrative procedures to get a connection to the water supply or sewerage system may disproportionately burden those who do not have the necessary documentation, or who have low levels of education or literacy.

Physical: Persons with disabilities, children, older persons, pregnant women and others often face physical barriers because of inappropriate design, such as limited space, facilities that require users to squat, small doors, or steps leading to the facility.

Geographical: People living in rural areas or in informal settlements in urban areas are often the last to gain access to services.

Economic: High construction costs, connection charges and tariffs can limit people's access to safe and affordable services.

Linguistic: People belonging to minority language groups may not be able to get information or participate in meetings; they may not be able to read and understand warnings, such as

notices informing people of the need to treat their drinking water, or letters advising of disconnections or interruptions in water supply.

Environmental: Some people face increasing environmental challenges due to pollution, dropping water levels or changing weather patterns. Other, environmental challenges such rocky terrain or soil collapse. Researchers should focus on the sustainability of water and sanitation services by developing strategies that holistically address the influence of the environment

Cultural: Many individuals and groups experience deeply entrenched stigmatisation, for example, ethnic minorities, 'low' castes, or homeless people. Often, people are confronted with multiple barriers simultaneously.

In an earlier study, the United Nations (2007) outlined reasons for the limited progress towards universal access to an adequate water supply to include high population growth rates in developing countries, and insufficient rates of capital investment in water facilities, difficulties in appropriately developing local water resources, and the ineffectiveness of institutions mandated to manage water supplies or to support community management in urban and rural areas.

Also, policy and decision makers have focused more on increasing coverage rather than focusing on how existing services provided can be manage sustainably. For example, in sub-Saharan Africa, a region with the highest need for an improved water service provision also has the highest number of non-functional handpump borehole (WHO, 2012). Beyond making service available to the people, there is a need to also explore approaches and methods that would make them last.

2.10 Sustainable drinking water coverage in Sub-Saharan Africa

Sub-Saharan Africa is the world's poorest and least developed region, with half its population living on less than a dollar a day. About two-thirds of its countries are rank among the lowest in the Human Development Index (UNDESA, 2014). According to WHO (2015), 319 million people are without access to improved reliable drinking water sources in the region. Globally, the regions have the greatest drinking water spending needs, with the greatest investment needs in rural areas (WHO, 2012)**.** Two-thirds of people still using surface water live in Sub-Saharan Africa (WHO/UNICEF, 2015)**.** The United Nations estimates that Sub-Saharan Africa alone loses 40 billion hours per year collecting water which is equivalent to an entire year's labour in all of France (UNDP, 2009).

Nonetheless, in the same region, since the year 2000, almost a quarter of the current population have gained access to an improved drinking water source (JMP,2015). This translate to an average, over 50,000 people per day, every day, for 12 years in a row. This shows that the region has made substantial progress towards achieving universal access to safe drinking water supply to the population. Figure 2.11 shows progress and trends in drinking water coverage percentage for sub-Saharan Africa, between 1990-2012. It shows a significant rise in the number of people using water from other improved sources from 33% to 48% as well as decrease in the proportion of people using surface water and unimproved sources.

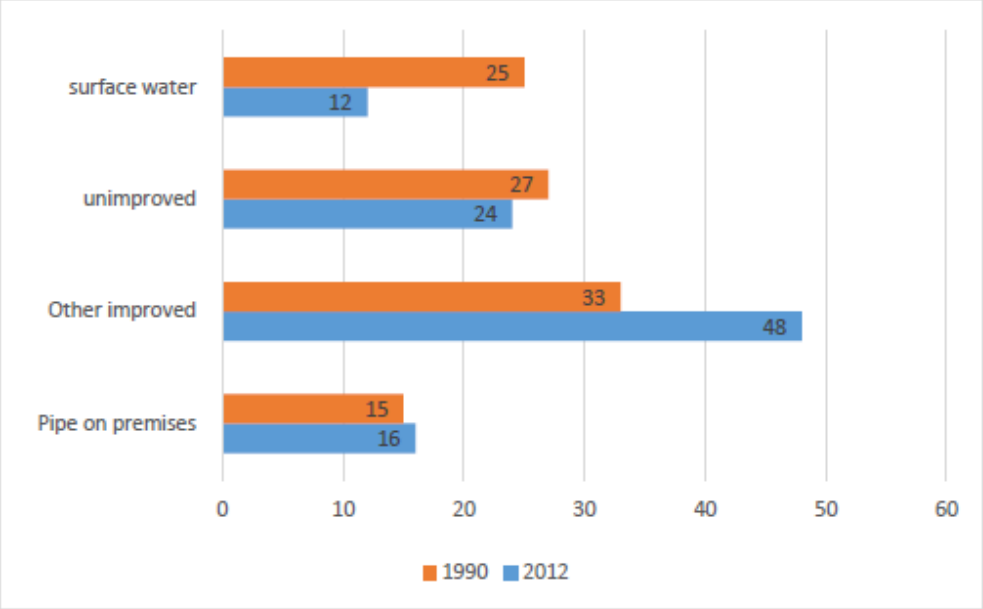


Figure 2.11: Drinking water coverage by Sub -Saharan Africa, 1990–2012 (Source: WHO/UNICEF 2014)

2.10.1 External aid to water supply provision in Sub-Sahara Africa

Figures 2.12 show breakdown of OECD regional financial investment, to water, sanitation and hygiene in developing countries around the world. The figure shows that 37% of the total external aid went to sub-Saharan Africa, which account for the largest share of the bilateral aid. Also, DFID (2012) bilateral programmes reported to have provided access to clean water drinking water to 2.7 million people during the period March 2008 - October 2009 around the world out of which 1.8 million people are in sub-Saharan Africa. However, this data on coverage and service provision do not reflect population whose water facilities have cease functioning or left in state of disrepair not long after facility was commission. These investments required that sustainability measures are taken to ensure these investments are not wasted to non-functionality in the region.

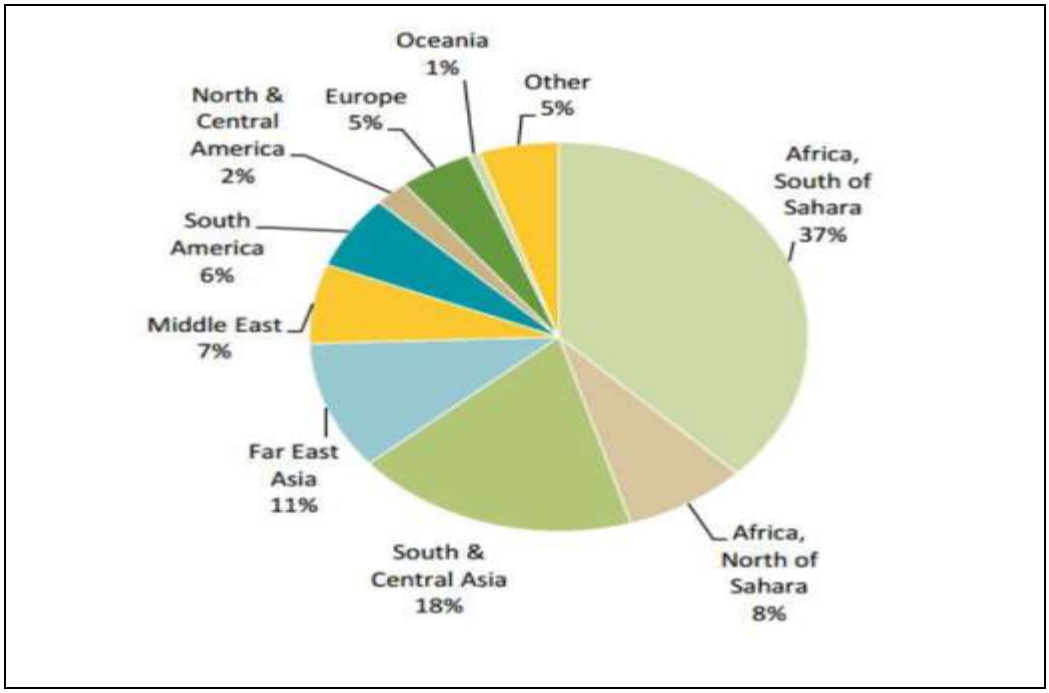


Figure 2.12: Regional Breakdown of Aid to WASH 2012-13
(Source: OECD, 2015)

2.10.2 Sustainable water service delivery challenge sub-Sahara Africa

Despite the advancement in the region discussed above, it is estimated that 40-50% of water facilities at any moment are non-functional (RWSN, 2009). Also, Moriarty et al (2010) noted that in the last three to four decades, substantial amounts of resources have been invested to provide water supply services in sub-Saharan Africa countries, however, studies have shown that most of these services are largely unsustainable. The commonly observed fact is that many programmes which started with the support of international agencies in developing countries have failed to deliver over there expected outcome overtime (Harvey, 2009).

The long-term sustainability of water service delivery has been a complex and persistent challenge facing communities, governments, and international development agencies. Significant proportion of communities already provided with water facilities can experience major failings in access to improved water sources within a few short years. These failings result in not only a loss of financial investment and community aspiration but also a very real threat to human health and wellbeing (Lockwood, 2014).

This failure rate and facilities breakdown attributed has been attributed to rapid population growth and poor economic development and poverty, insufficient financial resources and in the lack of institutional capacity, lack of coordination in the water supply sector as well as varied climate and natural hazards in the region (UNDESA, 2014). This call for the need to explore alternative approach aimed at ensuring water services continues to deliver services to households and communities over the lifespan of waterbfacilities. Figure 2.13 shows an estimated failure rate of handpumps in sub-Saharan African countries.

Typical examples of water facilities failure in some selected sub-Sahara Africa countries are discussed below.

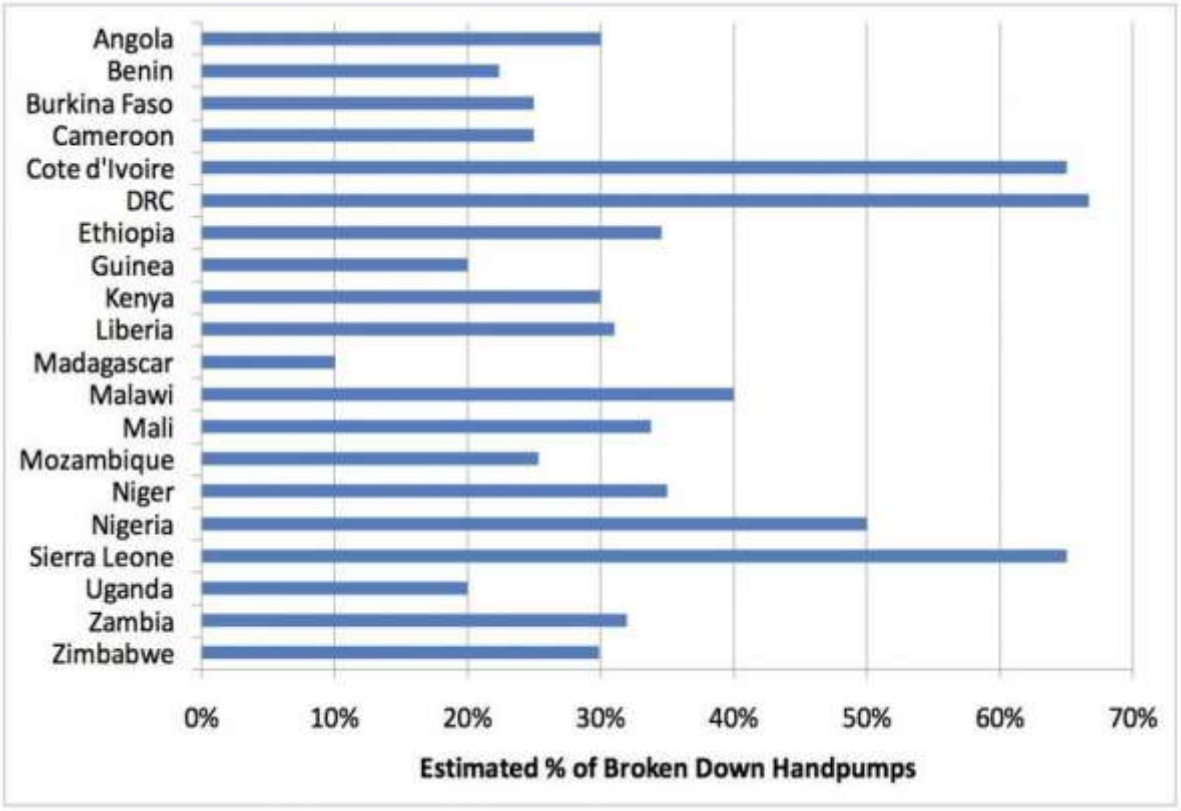


Figure 2.13: Estimated failed handpump in Sub-Sahara Africa countries. (Source: RWSN, 2009)

- **Ghana:** a survey conducted on Atebubu Water System, in the Brong Ahafo Region, served a group of eight urban communities with a total population of 32,000, found that the systems were completely non-functional at the time of the survey. It was observed that facilities filters were overgrown with weeds, standpipes had been shut down, and the chlorinator appeared run down. Many residents have resort to obtaining water from boreholes installed by the district assembly or by NGOs, (Ampadu-Boakye and Hebert, 2014).

- **Ethiopia**: a survey of 57 diverse water schemes showed 38.6% were non-functional on the day of the visit (Welle and Williams, 2014). Another study found non-functionality of rural water schemes in 10 regions ranges from 18% to 35%, with a national average of 20% (Calaw, Ludi, and Tucker, 2013).

- **Malawi:** a service level survey of 48 villages, found that 66% of handpumps installed in less than a year were non-functional (Shaw and Manda, 2013).

- **Tanzania:** a survey of 43 taps and 4 cattle troughs found that 11% were not functional on the day of the survey (Welle and Williams, 2014). A water mapping exercise of 55 of the 132-district showed that 43% of the water points were no longer working and that 25% of the water schemes had become non-functional within two years of installation (SNV World, 2014).

- **Uganda:** 19% of 79,413 water facilities surveyed are not working, as many as 2,303 facilities 2.9% are considered abandoned, having been non-functional for five or more years (Nekesa and Kulanyi, 2012).

- **Democratic Republic of Congo:** out of 2,051 water facilities in three provinces surveyed in Bas-Congo, Equateur and Kinshasa, non-functional water facilities were highest in Bas-Congo at 68%, 24% in Kinshasa and 14% in Equateur. In Bas-Congo only 39% of functional water points provided safe drinking water while in Kinshasa it was just 32% (Hambadiahana and Tolsma, 2012).

- **Sierra Leone:** a comprehensive water facilities mapping exercise of more than 28,000 water facilities surveyed in 2012, showed that the rate of damage of public water points is high and rises rapidly with the facility age. Among water facilities built in 2007, 31% are impaired, and 17% are broken down. Only about 40% of protected in-use facilities are providing insufficient water during the dry season (Sierra Leone Ministry of Water Resources, 2012).

- **Rwanda:** a baseline survey of 126 water points in the district of Kicukiro, showed that 50% of the water facilities had been down for more than 1 day in within 30 days, and 55% of the communities reported that they had no spare parts on hand for the water system (Water for People, 2011).

- **Kenya:** 1011 water facilities surveyed in 2010 pilot mapping showed average rates of non-functionality were 28% in West Pokot, 32% in Kyuso, and 20% in Mbeere, (David, 2013).

- **Nigeria:** about 80% of all government-owned water systems in small towns are non-operational (FGN, 2000)

- **Zimbabwe:** a study in Mt Darwin District found 38% of the boreholes studied not functioning. Average downtime for the boreholes was 3 weeks (University of Zimbabwe, 2009). Out of 817 deep boreholes, 65% were estimated to be out of order (Waterkeyn, and Cairncross 2005)

Moe et al (2006), summarise the main causes of water facilities failure as inadequate investment in water and sanitation facilities, lack of political will to tackle the obvious problems relating to facilities provision and management. Also, the tendency to downplay local initiatives, avoid inform technical choice and continue the implementation of conventional water supply intervention approach. This may not be inappropriate for benefiting communities and environmental needs. There is also the failure to evaluate interventions to determine whether they are successful and sustainable or not.

2.11 Chapter summary

This chapter presented an overview of global water resource and drinking water coverage, it highlights the importance and benefit of improved access to safe drinking water in human development, health and wellbeing. Notable milestone of global engagement towards attaining universal water services coverage were discussed. It also highlighted challenges to increasing safe drinking water coverage as well as ensuring service are sustainable were discussed.

It is clear from the foregoing that investment in water supply services can, and does, deliver results, however, the questions remain on how safe is the water? how affordable and reliable is the service? how sustainable are the water resources? these questions expose a knowledge gap that needs further interrogation, and critical review of sustainable water service delivery theories and concepts which form the basis for the subsequent chapter.

Chapter 3

3.0 Exploring sustainable water service delivery concepts

3.1 Introduction

The purpose of this chapter was to build the theoretical foundation upon which the research concept was based, review relevant literatures, explore current thinking, theories and concepts, as well as research knowledge gaps on sustainable rural water service delivery. It will also attempt to identify core sustainability drivers in order to established a basis for further exploration. The chapter also seeks to contextualise sustainable development and sustainability in the context of water service delivery.

3.2 Sustainable development concept

Many scholars have debated the meaning and definitions of sustainability and sustainable development. The Cambridge Dictionary (2003) defines sustainability as ‘able to continue over time; or causing little or no damage to the environment and therefore able to continue for a long time’. Brundtland (1987) defined sustainable development as: “development which meets the needs of the present without compromising the ability of future generations to meet their own needs.” It contains two key concepts:

- The concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and
- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

The above concept might have informed the Rio Declaration on Environment and Development, (1992), which define sustainable development as long-term continuous development of the society aimed at satisfaction of humanity's need at present and in the future via rational usage and replenishment of natural resources, preserving the Earth for future generations. However, Rowan (2002) argued that it is essential that ecological, social and economic threads of sustainable development are explicitly identified, but exactly what terminology is used is a matter of personal, organisational or disciplinary preference.

Robert et al, (2005) maintains that as a concept, the malleability of sustainability and sustainable development allows it to remain an open, dynamic, and evolving idea that can be adapted to fit very different situations and contexts across space and time. Likewise, its openness to interpretation enables stakeholders at multiple levels, from local to global, within and across activity sectors, institutions of governance, business, and civil society to redefine and reinterpret its meaning to fit their own situation. Therefore, there can be no universally appropriate form of words. It is, however, essential that any definition includes a plain language statement of what is meant by the words chosen (Rowan, 2002).

Four fundamental principles underlying sustainable development outlined by Bosworth, (1993) cited in Rowan (2002) state that;

- The Future**:** In any human activity, the effects of that activity on the ability of future generations to meet their needs and aspirations must be considered

- The Environment: The full and true environmental costs of any human activity must be taken into account
- Equity: Control over resources must be much more evenly distributed both within and amongst countries
- Participation**:** Development requires that people can share in decision-making about goals and about the means of development, and that they can also take an active role in pursuing them. This implies a degree of education about the process of development.

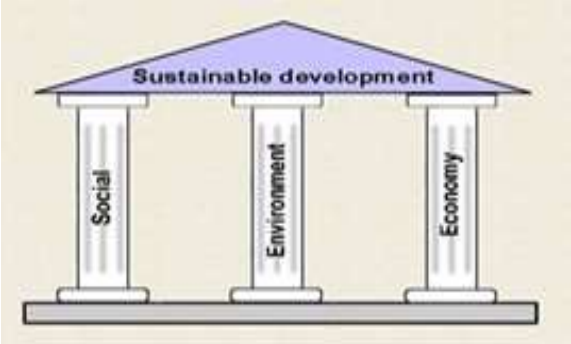
Figure 3.1 illustrates three sustainable development models that agree with Rowan's (2002) and Kate et al 2005 concepts of multifaceted understanding and interpretation of sustainability and sustainable development on global scale. Accoring to Rowan (2002) in an unsustainable development processes, three main pillars of sustainability which are; Economy, Environment and Society are treated as though they are separate entities and maximised with no regard for the interrelations involved (See Figure3.1 - model 1).

Willard (2014) described the overlapping-circles model which acknowledges the intersection of economic, environmental, and social factors intersecting at the central core for sustainability (see Figure3.1- model 2). It presents a more interactive concept of sustainability, ring that at any point in time the three underlying factors are constantly in-view rather than viewed as independent pillars describe as described by Rowan (2002).

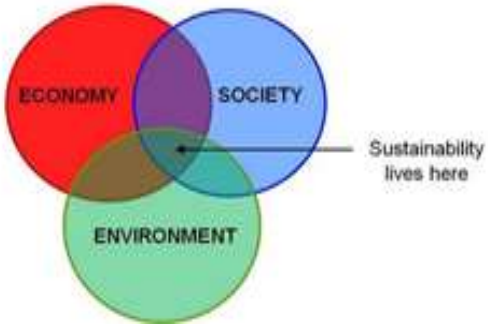
The 3-nested-dependencies model (See Figure 3.1- model3), according to Willard (2014) reflects a co-dependent reality. It argues that human society is a wholly-owned subsidiary of the environment. However, these concepts show an interdependence that must be considered in

exploring physical resources such as water to meet human needs. For the purpose of this research the overlapping circle model would be adopted as the concepts put sustainability at the centre of development, which require constant interplay between economy, environment and the society.

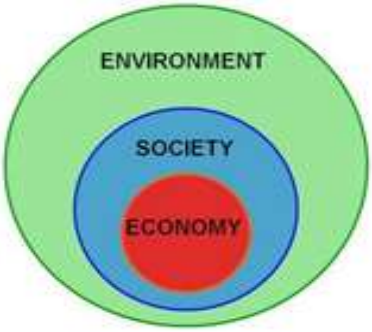
Sustainability models



Model 1. The three pillars approach



Model 2. The three overlapping circle model



Model 3. The Nested dependence model:

Source: Willard (2014)

Figure 3.1: Sustainable Development models
(Source: Willard, 2014)

3.3 Exploring water service delivery concept

The concept of 'sustainability' is used liberally in the water sector, and there are numerous interpretations of what this may mean in a wide variety of literature. In the specific context of the rural water supply, sustainability is defined, according to Lockwood, et al, (2003), as the maintenance of the perceived benefit of water supply investment projects (including convenience, time savings, livelihoods or health improvements) after the end of the active period of implementation. This definition is similar to Abrams (1998), that simply describes sustainability as: ''whether or not something continues to work overtime'' that is, whether or not water services continues to deliver services to communities or households over time (Lockwood and Smits 2011).

Sustainability Forum (2014) report described the concept as the maintenance of the perceived benefit of investments after the end of the active period of project implementation and whether services continue to deliver over time, and continues to provide an agreed level of service. It also proposes that sustainability expresses itself in the level of service received by users in terms of quantity, quality, accessibility and reliability of the water services delivered, which does not only describe whether the water services continue to be delivered, but also the characteristics of that services received.

This argues that the service levels depend on the performance in service delivery tasks at different institutional levels, covering:

- The performance of the service provider who carries out operation, maintenance and administration tasks

- Performance of the service authority responsible for planning, coordination, support and oversight roles
- The national enabling environment entities (Anon)

Hitherto, water sustainability is seen as whether or not services continues to deliver overtime, but, Carter et al (2006) further elaborate on the concept as implying the following ideas: the fact that the service continues to work shows that it is being used, its continued functionality implies that it is being maintained, its maintenance is being paid for, or it would deteriorate and the phrase 'over time' has no limit – that is the service, or some development of it, is permanent.

Similarly, (Mathew,2004) points out that sustained beneficial outcomes from a water facility can be considered as that which benefit the people, giving them a better quality of life in a way that is continued over time, and establishing within the community an expectation for a quality of service, that will be expressed as an actionable demand if the service is interrupted or removed. In a more encompassing description Brikke's (2000) defines water supply sustainability as follows (See Box 3.1).

Box 3.1: Brikke 2000 definition of sustainable water supply

Brikké (2000) defines a service as sustainable when:

- It functions and is being used.
- It is able to deliver an appropriate level of benefits in term of quality, quantity, convenience, comfort, continuity, affordability, efficiency, equity, reliability and health
- It continues over a prolonged period which goes beyond the life-cycle of the equipment.
- Its management is institutionalized (community management, gender perspective, partnership with local authorities, and involvement of formal / informal private sector)
- It's operation and maintenance, administrative and replacement costs are covered at local level (through user fees, or alternative financial mechanisms)
- It can be operated and maintained at the local level with limited but feasible, external support (technical assistance, training, monitoring).
- It does not affect the environment negatively.

(Source: Brikké, F, 2000)

The Brikke definition, tend to provide the fundamentals for any water facility to delivers services sustainably. It goes beyond just measuring of functionality but also touching on social, institutional and the environment components of water supply sustainability.

3.3.1 The concept of continued external support

Carter et al (2009) claimed that the sustainability of community-based water and sanitation facilities involves a chain of four essential interlinked components such as motivation,

maintenance, cost recovery and continuing support. He argued that failure of any one the links will endanger the entire system. Figure 3.2 described these components of sustainability water service sustainability according to Carter et al., (1999) as an interlinked and interconnected mechanisms rather than a straight chain.

The idea support the argument that the failure of water facilities is attributable to the non-involvement of the intended beneficiaries, either at the point of initiation/conception, funding, execution and monitoring, among others as well as the lack of continued external support which is required for facilities to function sustainable according to (Carter, et al. 1999, Webster, et al. 1999, Harvey and Reed 2004, Carter and Rwamwanja 2006, Lockwood and Smits 2011).

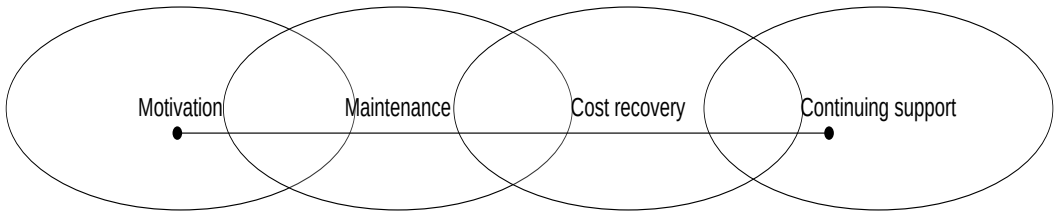


Figure 3.2: Diagrammatic representation of sustainability chain (Source: Adapted from Carter et al, 1999)

Komives, et al., (2008) found that the concept of post-construction continuing support, which involves refresher technical training for water point caretakers and regular visits by district water and sanitation local government officials are important aspect of post-implementation support toward sustainable services. Similarly, Braune and Xu, (2010) proposed that

governments and development partners must significantly strengthen post construction support for operation and maintenance facilities.

However, due to the limitations faced by local authorities in many developing countries, undertaking post construction support could be very challenging. Hence, a need for realistic approach to water services delivery which emphasis on the need to test and evaluate alternative models for managing water facilities in developing countries (Braune and Xu, 2010). Table 3.1 summarises key components considered necessary for water supply sustainability in Sub-Saharan Africa. It identifies sustainability components, enabling factors, main obstacles and suggestion on how to overcome such challenges (Montgomery et al, 2008).

Table 3.1 Sustainability components
(Source: Montgomery et al, 2008)

Sustainability component	*Enabling factors*	*Main obstacles*	*Overcoming the challenges*
Effective Community Demand	Participatory planning Appropriate technology choice Social marketing	• Physical isolation • Limited time and resources • Lack of incentives • Technology based on donor preference • Little awareness regarding social marketing approaches	• Earmark sufficient planning funds in project budget • Select technology based on local choice and socioeconomic conditions • Promote neighborhood, person-to-person behavior change messaging • Develop local critical thinking skills in schools
Local Financing and Cost Recovery	Local borrowing and saving schemes Financial planning Community cross-subsidies	• Lack of financing services • Bureaucratic process for obtaining loans • Limited knowledge • Mistrust of local water/sanitation (wat/san) funds	• Enable communities to establish their own funding schemes • Provide training and ongoing support for financial planning • Create system to allow for equitable access to water and sanitation services
Dynamic Operation and Maintenance	Clear management responsibilities Accessible spare parts/technical expertise Monitoring/evaluation (M&E) Ongoing outreach and support	• Lack of consensus on responsibilities • Isolation of rural communities • Local technicians not supported financially or provided with ongoing support • Lack of incentives for funders to provide long-term support	• Facilitate open discussion • Create community-based financial plan • Including main users in decision-making process • Allocate funds for M&E in project budget • Formalize operating procedures, including through private entity

From a broader perspective WaterAid proposed a sustainability framework for externally supported community-based water facilities. The concept described sustainability as whether or not water services continue to work and deliver benefits over time. According to this concept, there is no time limit set on those continued services, behaviour changes and outcomes. In other words, sustainability is about permanent beneficial change in water, sanitation and hygiene services and practices (WaterAid, 2011).

The concept is hinged on the premise that once change for improved water services has been brought about, then that trajectory of change must be maintained and enhanced. If for any reason communities slip back into a situation where they have to rely on unsafe water services, then investment to improve water access and coverage in the community has effectively been wasted. Figure: 3.2 and Box 3.3 attempt to explain the conceptual framework for effective externally supported community-based management of rural water supply.

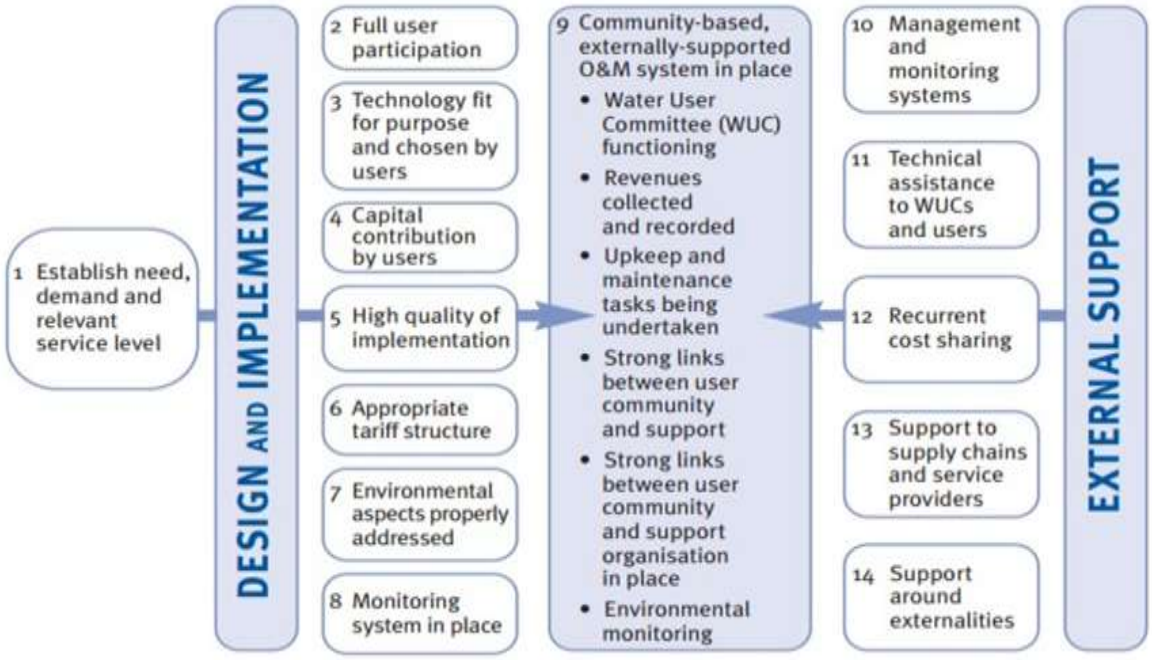


Figure 3.3: Conceptual framework management rural water services (Source: WaterAid, 2011)

Box 3.3: Figure 3.2 Explanatory notes

The explanation below is an attempt to provide an overall understanding of the necessary components for sustainable water service delivery.

- First, without real need and demand there is little or no prospect of changed practices being sustained
- Second, there are several aspects of programme design and implementation which are fundamental to the achievement of effective and sustainable community-based operation and maintenance
- The evidence of a functioning community-based management system is to be found in the existence of an active water user committee, sanitation committee or equivalent, and the others aspects shown in the central shaded box
- External support to the community management system is needed in relation to the various aspects shown
- Normally such external support would come from national and local government, together with private suppliers of goods (such as spare parts) and services (such as repairs). The existence of national policies and budget lines which reflect the need for external support, and a regulatory framework surrounding private providers, are essential aspects of the enabling environment.

Similarly, Schouten and Moriarty (2003) also agree that once a community has been provided with a given level of service it should never have to revert to a structurally lower level of water service in terms of quantity or quality. This implies that systems are maintained not only during its natural lifetime, but will also eventually be replaced or upgraded.

Figure 3.4 shows a ladder of gradual improvement in the level of service accessible to user. This is based on understanding that the benefit derived on improved service will engender a motivation for even better level of service. However, this concept may remain to very large extent unrealistic due to frequent services breakdown and record levels of non-functioning facilities in many developing countries. As result investment that should be considered for an upgrade may be lock into cycle of repairs and rehabilitation. There the concept of continued support for sustainability in this regard entails providing sustainability services and supporting communities to keep services functional as well as expecting a gradual improvement in the level of services users can access.

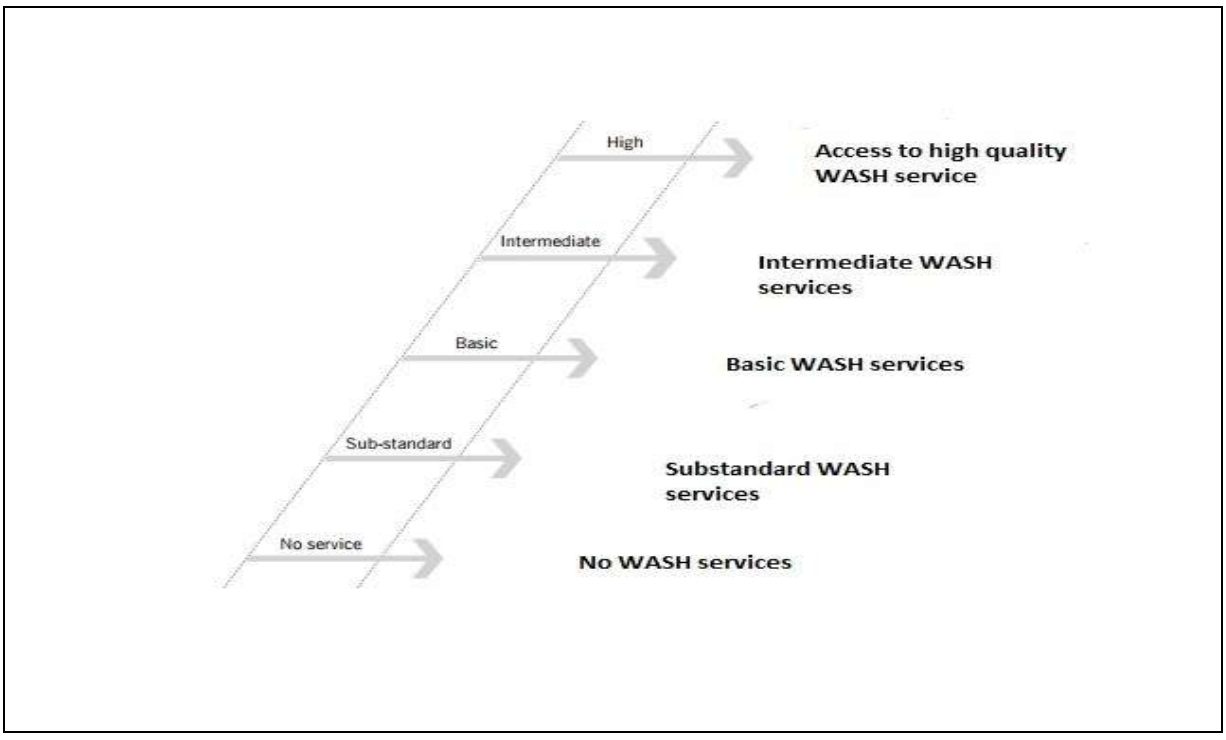


Figure 3.4: Service delivery and sustainability service ladder (Source: Adapted from Moriarty, et al., 2010)

Nevertheless, a major challenge with post-implementation continuing external or an ongoing outreach is that it is not sustainable in the long-term due to human, material and financial

constraints in part of local authorities, limited human and financial resources available are more likely to be deployed to water service expansion rather than being devoted to maintaining existing facilities.

Contrary to the concept of post-implementation and continuing support to keep services functioning, Parry-Jones et al, (2001) concluded from a wide a range study of various sustainability drivers that the most frequently recurring issues were:

- Minimal external assistance in the long term
- Financing of regular operation and maintenance costs by users; and
- Continued flow of benefits over a long period.

Also, Harvey (2008) enumerated eight factors considered to be critical to achieving sustainability as follows;

- Policy context;
- Institutional arrangement;
- Financial and economic issues;
- Community and social aspect;
- Technology and the natural environment;
- Spare parts supply;
- Maintenances systems;
- Monitoring;

From the above argument suggest that sustainability depends on many factors, including participation by communities and households in planning, design, implementation, operation and maintenance; a range of technologies that are within the means of communities and households to operate and maintain; the existence of functional supply chains for spare parts and supplies; the technical, financial and institutional support capacity of intermediate-level actors; and the existence of enabling and supporting legislation.

Therefore, to achieve a sustainable rural water supply services, there is a need for greater interconnectedness between technology, environment, supply chain, financing and management, supported by enabling policies. Harvey and Reed (2004), however, stressed that sustainability cannot be achieved by focusing on one factor in isolation, each factor contributes to sustainability but may not provide the solution in themselves. It is essential, therefore, to understand the role each factor plays and the relationship between them. These constitute key knowledge gaps in delivering sustainable services in developing countries. This suggests that there is no one size fit all sustainable solution. Rather, exploring opportunities and linkages between various factors may hold the key to services sustainability.

In a more recent study UNICEF and WHO (2015) aligned with the concept that a water service is sustainable if it continues to deliver the designated level of service with respect to affordability, availability, quality, and accessibility over the long term. Montgomery et al, (2009) therefore recommended that the community of engineers, scientists and field practitioners use; effective community demand, local financing and cost recovery and dynamic operation and maintenance as a basis for rigorous inquiry into sustainability of water and sanitation facilities.

3.4 Why explore sustainable water service delivery

For more than 40 years, aid agencies, governments and others have focused on short-term projects and new infrastructure, counting and celebrating new pumps and pipes. Far too often, these have been provided as isolated, unsustainable, one-off gifts but is now clear that simply installing a pump is not enough, (IRC, 2013). Figure 3.5, shows global water facility failure rate (based on "snapshots" of functionality for hundreds of thousands of water facilities) has been around 40% since the 1990s (Improve International, 2014)

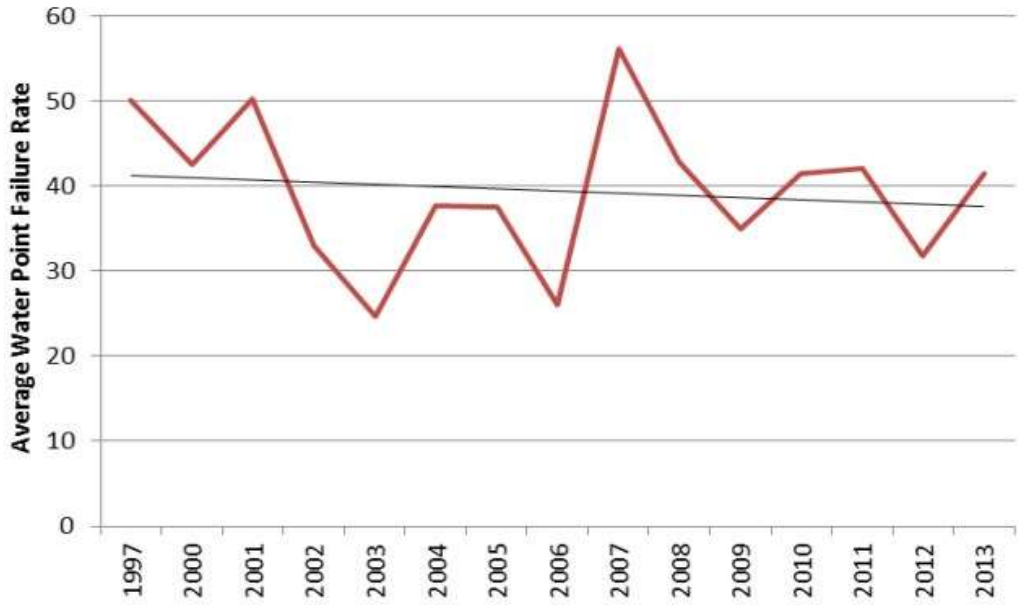


Figure 3.5: Average global water facility failure rate percentage in developing countries. (Source: Improve International, 2014)

As a result, over the years attention has been devoted to finding ways in which partnerships of institutions from very different origins, non-government, private, public and academic can be brought together to innovate, develop policy, provide accountability and deliver sustainable

services in the water sector (Caplan, 2003). In 2011, nearly 100 stakeholders from over 50 organisations came together to develop a common set of principles, known as the Water supply, Sanitation and Hygiene (WASH) Sustainability charter. The underlining principles are as follows;

- The lasting provision of safe water, sanitation, and hygiene education (WASH) is a leading development priority of our time. Around the world, almost one billion people live without access to improved water sources, while 2.6 billion people live without access to adequate sanitation facilities
- The lasting provision of safe water, sanitation, and hygiene education is key to sustaining human health, education, and economic development, empowering women, and maintaining ecosystems that support all life
- Sustainability requires the development of meaningful partnerships that recognize the diverse roles of all actors, including communities, governments, donors, implementers, and all other stakeholders
- Efforts to promote ongoing safe water, sanitation, and hygiene education are critical to the stability and development of communities around the world and can end the needless suffering and premature death of men, women, and children due to waterborne illness
- There are still enormous systemic challenges to providing sustainable safe water, sanitation, and hygiene services in many countries. Most critically, many of those who may have benefited in the short-term from WASH projects now have systems that are not working adequately, or have failed completely.
- The premature failure of these solutions is unacceptable (Banks, 2011)

On the premise of the above charter, it is obvious that providing new infrastructure to unserved populations is imperative. However, it is equally important to ensure that both new and older services are sustainable. It also stressed that increased coverage in water services cannot be obtained simply by drilling more boreholes or even by training more community management groups without giving adequate attention to their sustainability.

There is a recognition that the underlying causes of premature breakdown and poor service levels stem from an unbalanced focus on building infrastructure. It is opined that this should rather be on facilitating the continuity of services associated with that facility by creating the appropriate enabling environments at all level. Furthermore, account needs to be taken of the realities of frequently poor levels of functionality. It is relatively easy to increase coverage through construction of water supply systems, but it is much more difficult to ensure that such systems continue to provide service over the long term (United Nations, 2007)

Boulenouar et al., (2013) maintain that even though well-designed water facility remains a core part of service delivery, it is also necessary to invest in support services, financing mechanisms, monitoring and a range of other interventions that collectively result in services being maintained over time. According to Lockwood (2014) expanding inquiry beyond simply the physical water facilities s and assessing what is or in many cases what is not happening around water facilities at the level of operators, districts or municipalities, and even the nations is important, where supportive policies and legislations can be develop to have a direct impact on sustainability in the community. Ademiluyi and Odugbesan (2008) also concluded that making sure water facilities continue to deliver may only be achieved through considering evolving and adaptive delivery mechanisms.

3.5 Towards sustainable water service delivery

Lockwood and Smit (2011) refers to services as the provision of a public benefit through a continuous and permanent flow of activities and resources; a concept applied in many other services, both in the developing and developed worlds, such as health, education, electricity, telephone and urban water supplies. Figure 3.6 shows Lockwood and Smit's (2011) strategic stages in service delivery approach, which shows linkage between strategy and the project cycle.

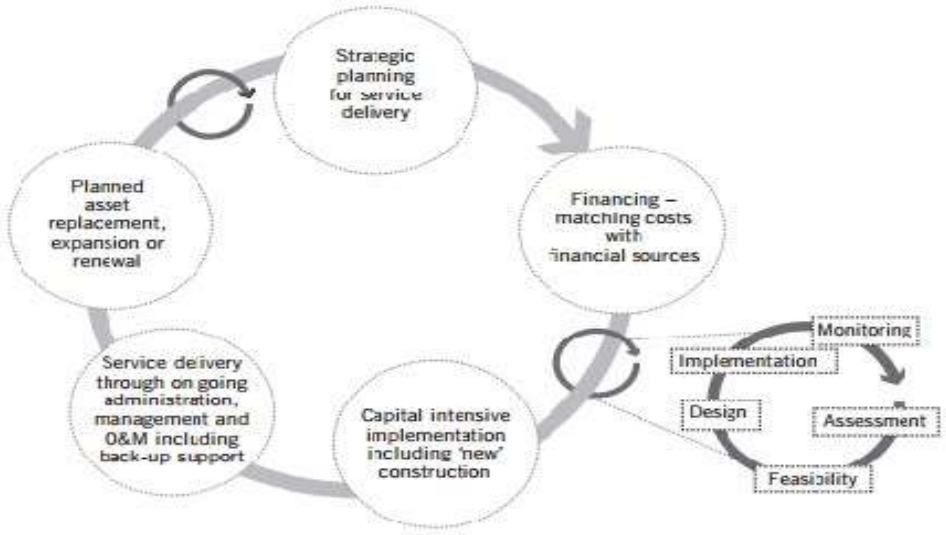


Figure 3.6: Stages in the service delivery cycle
(Source: Lockwood and Smits, 2011)

In water service delivery sector, a range of approaches, methodologies and tools have emerged to support water services deliver sustainably. A Cranfield University, IRC and Aqua- consult (2006) review identified three broad approaches to service provision as:

Externally driven approaches: these are projects initiated by agencies other than the water users, and usually heavily subsidized. Studies have shown that much of these externally driven-bilateral aids for water supply fails to achieve the kind of balance between soft and hard infrastructure that can support water services sustainability. The 2009 World Water Development (WWDR) pointed out that for investment to be sustainable, physical infrastructure must be accompanied by the 'soft' infrastructure of policies and legal systems and human capacity.

Figure 3.7 shows major bilateral donors share investment in water and sanitation with majority percentage going into water facilities. From the diagram, it is clear that more than three-quarter of investment in drinking water were made for the provision of physical facilities at the expense of developing social and institutional structure. Table 3.2 summarised service delivery approach usually deployed by external support agencies toward water supply intervention in developing countries.

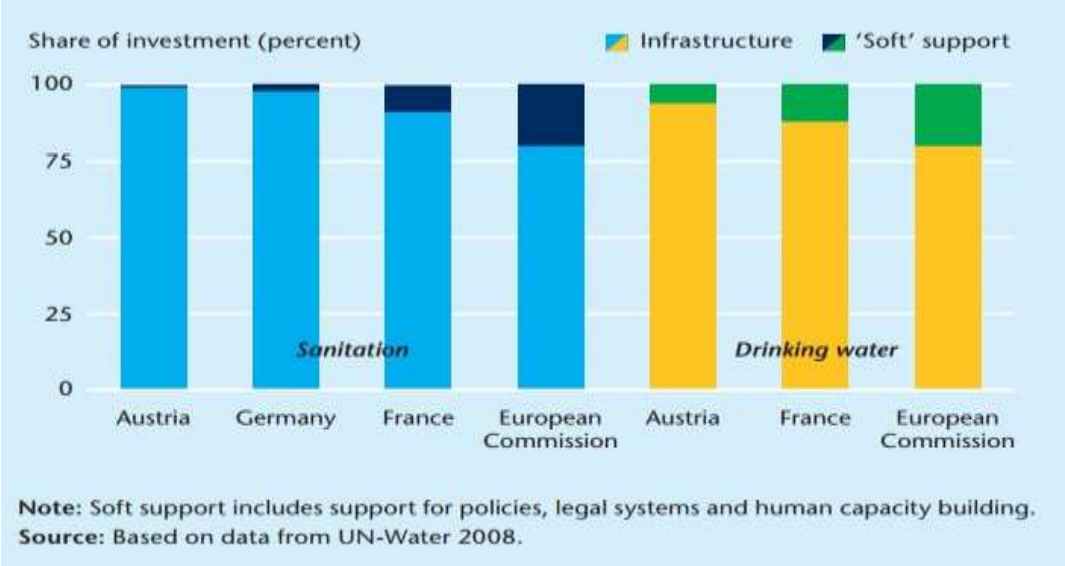


Figure: 3.7 Donor investment in water and sanitation infrastructure (Source: Adapted from WWDR, 2009)

Table 3.2 Comparison of service delivery approach in relation to sustainability factors. (Source: Harvey, 2008)

Sustainability factor	Project	Programme
Policy context	The influence on policy is minimized by the time-frame of the project	There is potential to develop advocacy strategies to influence long-term policy and strategy change
Management and institutional arrangements	Projects are often donor-driven and implemented by NGOs / consultants who leave the area after a finite period	Local government and sustainable institutions in partnership with the private sector take the key roles
Community and social aspects	The need for a project 'handover' transfers all O&M responsibility to users with little or no external support	Sustainable partnerships can be developed over time and ongoing institutional support provided to communities. Communities are given choice to be or not be service-provider
Financial issues	Time-bound budgetary requirements limit sustainable financing mechanisms Users pay for maintenance and upkeep of a single facility only	Budgetary allocations can be made for institutional support for communities and long-term incremental strategies Users pay for water service which includes the cost of asset replacement for which subsidy may be available
Technology	Technology choice often remains rigid with a finite lifespan and there is no time to investigate longer-term solutions	Allocations for research and development can investigate alternative technologies A flexible approach to technology is adopted allowing it be upgraded over time and respond to environmental changes
Environment	Initial environmental assessments may be conducted during construction but there is no follow- up	Long-term strategies can be put in place to monitor water resources and environmental issues
Supply chains	The need for an exit strategy has led to the idea of a 'seed fund' for private spare parts supply - this has not worked Maintenance and repair focused on the specific facilities	Long-term strategies can be put in place to monitor water resources and environmental issues

Notable with the externally driven approach is the introduction of community management of water facilities as a strategy towards sustainability briefly discussed in section below.

Enterprise-driven approaches: This is an approach in which local private entities supply goods and services to governments, nongovernmental organizations (NGOs), or water users directly engage in the water service provision based on the principle of demand and supply with a view to making profit. RWSN (2010) noted that debates about private sector participation and public–private partnerships for the improvement of water supply services have generated more heat than light.

Foster (2012) argue that although the private sector offers a promising pathway to improve the provision of water services in rural areas, full recovery of capital costs through user fees appears to be rare, particularly in rural Africa, thus widespread capital investment by private enterprises and entrepreneurs remains unlikely without external subsidies. Thus, there is little doubt that the private sector is unlikely to invest significant sums to modernize or extend water supply systems (Davis, 2005).

Self-supply initiatives: This is an initiative where users take responsibility for their water supply facility from construction to operation and maintenance without subsidy from government or external support agency. Details of this approach are explored and discussed in chapter 5. According to Oluwasanya (2006) self-supply have been shown to be water supplies initiated through self-help to bridge the gap between public and community provided sources.

3.6 Community managed water facilities

According to Schouten (2006) community management has evolved to become a leading management model in water service delivery. The objective always is to make the community responsible for the operation and maintenance of onsite water facilities after the implementing agency has left. Different levels of community management are categorised as follows:

- For some, community management means that community members help to construct the water facilities. They dig the trenches and they supply and carry the local materials such as stones and sand;
- Another important element of community management is that the people in the community contribute to the costs of the water facilities (in general some 5 to 10%) and pay 100% of the money needed to operate and maintain the facility;
- For many, community management requires participation of a cross-section of the community in the process of developing water services, most importantly in the design of water facilities and the choice of the service level and how the costs for operation and maintenance should be recovered and so on; and
- For most external agencies community management is putting in place everything that is needed to enable the community to manage its water service indefinitely. The most important elements of such a management system are an elected water committee to take the important decisions, effective systems of book keeping and minute taking, by-laws prescribing the rights and obligations of the users, an operator to maintain the water systems in the communities.

The approach has contributed significantly to improvements in rural water supplies and has been recognised to be critical for rural water supply services (Carter et al 999, Harvey and Reed 2004, Wallerstein and Duran, 2010). However, those supplies are only sustainable when communities receive appropriate levels of support from government and other entities in their service delivery tasks but it has limitations, particularly when it comes to the ability to sustain services over the long-term (DFID, 2016).

Much rural water supply in Africa are community managed. However, it has been recognised as one of the important reason why sustainability of such water facility is often poor and fail to sustainable. The challenge to operate and maintain low-cost technology such handpumps in community managed water facility has been problematic due to mainly technical and financial reasons (RWSN, 2009). Therefore, exploring a knowledge gap that exists in considering an alternative approach from community managed water facility to a decentralise system of individuals or cluster household that minimise both construction and operation cost will be vital to achieving sustainability in rural water supply.

3.7 Exploring sustainability tools

In an attempt to overcome failure in externally driven water facilities delivery approach, several external support agencies have developed what are known as sustainability tools. These are set of guidelines, framework or procedure design to ensure services last beyond implementation. Table 3.3 shows some selected water service delivery related tools used or proposed mainly by external agencies. The major challenge with these tools is that they were conceptualise and developed by experts with limited or no consultation with local partners or beneficiary

communities. This hampers the efforts of the proponents to ensure that they are used sustainably to achieve an acceptable level of service.

Table 3.3 Highlights of water facilities sustainability tools of 2013 (Source: Banks, 2013)

Sustainability tool	Description
Participatory Hygiene and Sanitation Transformation (PHAST) - step by step guide: a participatory approach for the control of diarrheal diseases	The guide presents a seven-step approach to help people feel more confident about their ability to take action and make improvements to their communities using participatory techniques.
Sustainable sanitation and water management toolbox	This integrative toolbox is used for capacity development at the local level. It offers material covering: clarifying the sustainable sanitation concept, understanding existing local water management systems, planning and process tools, implementation tools, and train the trainers modules
Developing Financing Strategies in Water Supply and Sanitation	This tool provides information about financing strategies in water supply and sanitation (WSS) that are realistic and meet established development objectives. It addresses the preparation, development and implementation of a financing strategy in WSS in developing and transition countries.
Operation and maintenance of rural water supply and sanitation systems: A training package for managers and planners	This training package provides activities for planners and managers interested who are challenged by the effective implementation of WASH Operation and Maintenance services in developing countries. It highlights the importance of community participation, gender balance, emphasizing the efficient use of local human resources for sustainability
International Standard Organization ISO Water Standards	The presents three key standards for managing water utilities, and assessing water services necessary for abstracting, treating, distributing or supplying drinking water and for collecting, treating and disposing of wastewater as well as for providing the associated services and evaluating the service being delivered.
Self-Esteem, Associative Strengths, Resourcefulness, Action-Planning, and Responsibility (SARAR) techniques: Tools for Community Participation, a manual for training trainers in participatory techniques	The SARAR approach to community participation in development projects is designed to ensure that sectoral improvements correspond to people's priorities and benefit from people's willingness to use them effectively and maintain them in good order.

3.6 Drivers of sustainable water service delivery

From earlier reviews, it can be argued that for a community to keep water facilities operational over time requires a dynamic, inter-linked, interdependent and a complex mix of managerial, social, financial, institutional, environmental and technical issues. Similarly, Washalliance consider Financial, Institutional, Environmental, Technological and Social (FIETS) as main five sustainability drivers in concept called the (FIETS) sustainability model (Washalliance, 2013) which advocate that users should be responsible for ensuring the sustainability of their water facilities without reliance on external support. It is a model that promotes user ownership and acceptance of responsibility for the post- construction operation without little or no reliance on external support.

This concept will require that communities are able to managed facilities without soliciting or continuing external support. However, the community-managed system has been established to be challenging. Therefore, exploring a household option that can engender absolute responsibility on the user would be pertinent. Therefore, this study will subsequently explore the five sustainability drivers as the core underlying concept of this research in relation to household managed approach. Figure 3.8 illustrate how the interconnectedness between sustainability factors. Service are likely to fail where on or more of these link is weak, therefore in an attempt to ensure services are sustainable any weak-link must identify and addressed.

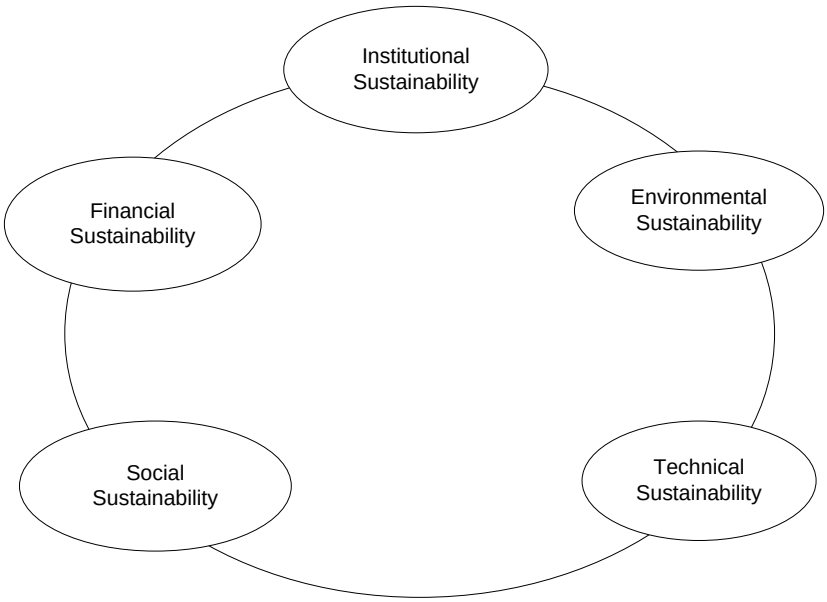


Figure 3.8: FIETS sustainability approach (Source: Washalliance, 2014)

3.6.1 Financial factor:

This means that continuity in the delivery of water services is guaranteed, because the activities are locally financed (e.g. taxes, local fees, local financing) and do not depend on external subsidies. Figure 3.9 illustrates the difficulty experience at post construction, operation and maintenance stage of many water facilities in developing countries. It shows a typical cycle of how lack of financial sustainability in many water facilities operation, return users to unsafe practices. This situation is often associated with community based water supply where users are expected to be responsible for operation and maintenance.

Carter (2009) noted that the failure of an existing water facilities is often due to weak financial and management arrangements for operation and maintenance, and a mismatch between the technology, the water environment, and the capacity of users to maintain systems. Howard and Bartram (2005) also, noted that a lack of financial resources constrain both the maintenance and expansion of services.

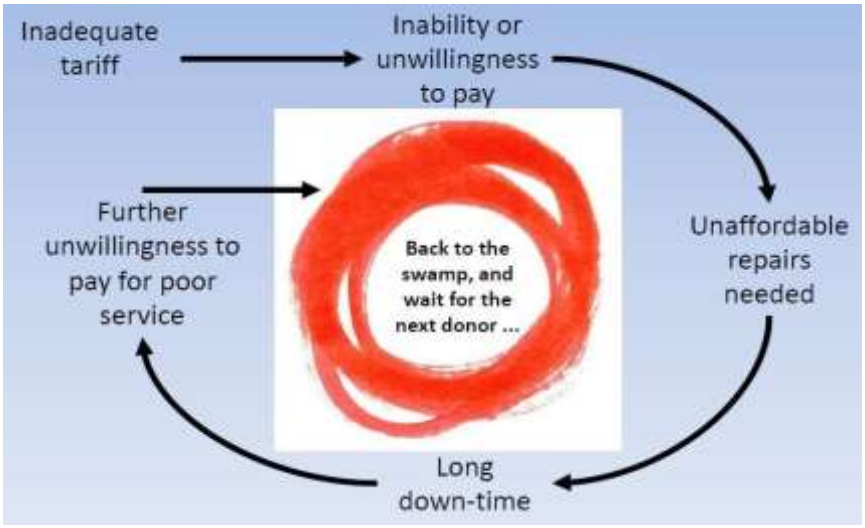


Figure 3.9: Myths of Rural Water Supply and directions for change (Source: RWSN, 2009)

3.6.2 Institutional factor

Gleick (1998) believed, for water services to be truly sustainable, there must be a social system or institution capable of controlling and managing supply to meet demand and different priorities of water use in different circumstances. Institutional sustainability in the water sector means that water systems, institutions, policies and procedures at the local level are functional and meet the demand of users of water services. That is households and other water service users, authorities and service providers at the local, state and national level are clear on their

own roles, tasks and responsibilities, can fulfil these roles effectively and are transparent to each other.

3.6.3 Environmental factor

The element of environmental sustainability implies placing water interventions in the wider context of the natural environment and implementing an approach of integrated and sustainable management of water resources. Unfortunately, the drive for increase water service delivery and coverage has given little or no priority to water sources sustainability. This particularly important for ground water resources. These is further explored in details in chapter 5.

3.6.4 Technical factor

According to Harvey and Reed (2004) an intervention must reflect the needs and the capacity of local communities to carry out operation and maintenance. Hunter et al (2010) acknowledged that technologies are only manageable if the right skills, resources, and incentives exist, and if appropriate support structures are provided.

Technical sustainability of water services is reached when the technology or hardware needed for the services continues to function, is maintained, repaired and replaced by local people and it is not depleting the natural resources on which it depends for to function over time (Washalliance,2014). This research seeks to explore such technical solution in delivery rural water services.

3.8.5 Social factor

This refers to ensuring that the appropriate social conditions and prerequisites are realized and sustained so that current and future society is able to create healthy and liveable communities. Social sustainable intervention is demand-driven, inclusive (equity), gender equal, culturally sensitive and needs-based. Da Silva et al (2010) found that there is a need for local and national authorities to promote dialogue between communities in order to build user confidence and consciousness as well as the opportunity for participation in decision making.

3.7 Chapter summary

This chapter presented the general idea of sustainability and sustainable development concept, and how it is linked to sustainable water service delivery. Several sustainable water service delivery concepts reviewed can be broadly categories into proponents of sustainable water service delivery based on the concept that promotes post implementation, or continuous external support and that encourage little or no external support after intervention. However, continuous external support will suffer setbacks due to limited human and material resources and priority being to expand services coverage to unserved communities. Although, both concepts share is a common idea of perpetual service benefits, upgrades and improvement, non-emphasis the need to protect water resources from an environmentally sustainability perspective. Therefore, this study will explore the option in the later concept from an environmental standpoint.

The review also established the need for an inquiry into sustainable services is necessary due present level of water facilities failure in developing countries. It was also clear from literature

that expanding inquiry beyond simply the building water facility and assessing what is or in many cases what is not happening in the communities and around these water facilities is necessary. Three main service delivery approach were noted such; Externally driven approach, Enterprise driven-private sector driven, and Self-supply initiatives. While Externally driven approach is often associated with failures, enterprise driven private sector has a peculiar challenge with demand and supply while self-supply that promotes user initiative, ownership and responsibility may hold the key to sustainable water delivery.

Five core drivers of sustainability were identified as financial, institutional, environmental social and technical factors. This research will explore the concept of sustainable water service delivery based on drivers at the community and household level with a view to find alternative option that is manageable at household level as basis for subsequent enquiries.

Chapter 4

4.0 Review of Nigeria drinking water supply coverage

4.1 Introduction

The objective of this chapter is to provide general background on the Nigerian state, and provide insight on water sector development, institutional policies, roles and responsibilities. It will discuss current thinking, trends, and service delivery coverage in rural, small town and urban communities. It will also provide insight on implications of unsustainable water supply and challenges to sustainable services with a focus on rural water supply, as well as identify knowledge gaps, justifying the need for in-depth research on the subject matter.

4.2 Nigeria country profile

4.2.1 Location and climate

Nigeria is located in West Africa, between latitudes 4^{o} 1' and 13^{o} 9' North, and longitudes 2^{o} 2' and 14o 3' East. It is bordered by Niger to the North, Chad and Cameroun to the East, Benin Republic to the West, and Atlantic Ocean to the South with a coastline of about 800 km. The country has a total surface area of 923 770 km2 with a land area of 910 770 km2 and a water area of 13 000 km2 (Ince et al, 2010). It is composed of 36 states, 774 local government area and the capital city is Abuja (WSA, 2011). The country is grouped into six geopolitical zones namely; North Central, North East, North West, South East, South, and South West as shown in Figures 4.1. There are about 374 identifiable ethnic groups, with the Hausa, Yoruba, and Igbo being the major groups (FGN, 2013).

Figure 4.1: Map of Nigeria
(Source: NDHS, 2013)

According to the World Atlas (2015) Nigeria's climate varies from equatorial in the south with mangrove forests and swamps bordering the southern coast, and hardwood forests further inland, to tropical in the centre and arid in the north. Annual rainfall varies from over 4000 mm in the south to less than 250 mm in the north, the national average being 1180 mm.

Rainfall is seasonal with a wet season occurring between July to September in the north, extending to between April and November in the Delta area. The mean annual temperature in northern Nigeria is around 25ºC (Alagbe, 2002), The northeast, however often experiences greater extremes with temperatures as high as 44°C before the onset of the rains and as low as 6°C between December and February (Aizebeokhai, 2011).

4.2.2 Demography

Population is estimated at 174 million based on 2.8% growth in accordance to 2006 national census figures, (NBS, 2013). Figures 4.1 shows the country steady rise population since 1920. An average population density for the country was estimated at 150 people per square kilometre, (NPC,2014). According to (World Population Review, 2014) projected population of Nigeria will reach about 440 million by the end of the year 2050. This is illustrated in Figures 4.3. Hence, if the current trend in population growth rate continues, by 2100, Nigeria will be over 900 million. (See Figure 4.3)

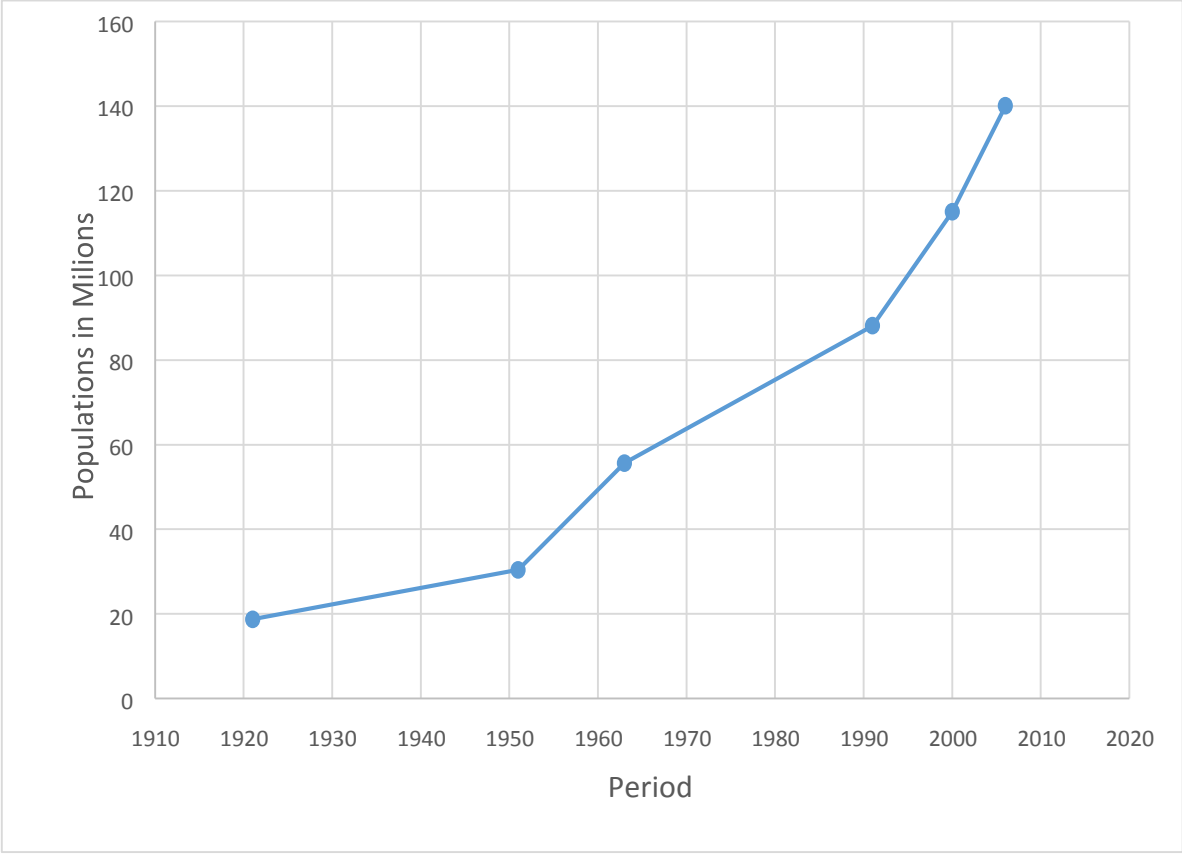


Figure 4.2: Nigeria population growth rate 1920-2010
(Source: Population Reference Bureau, 2013)

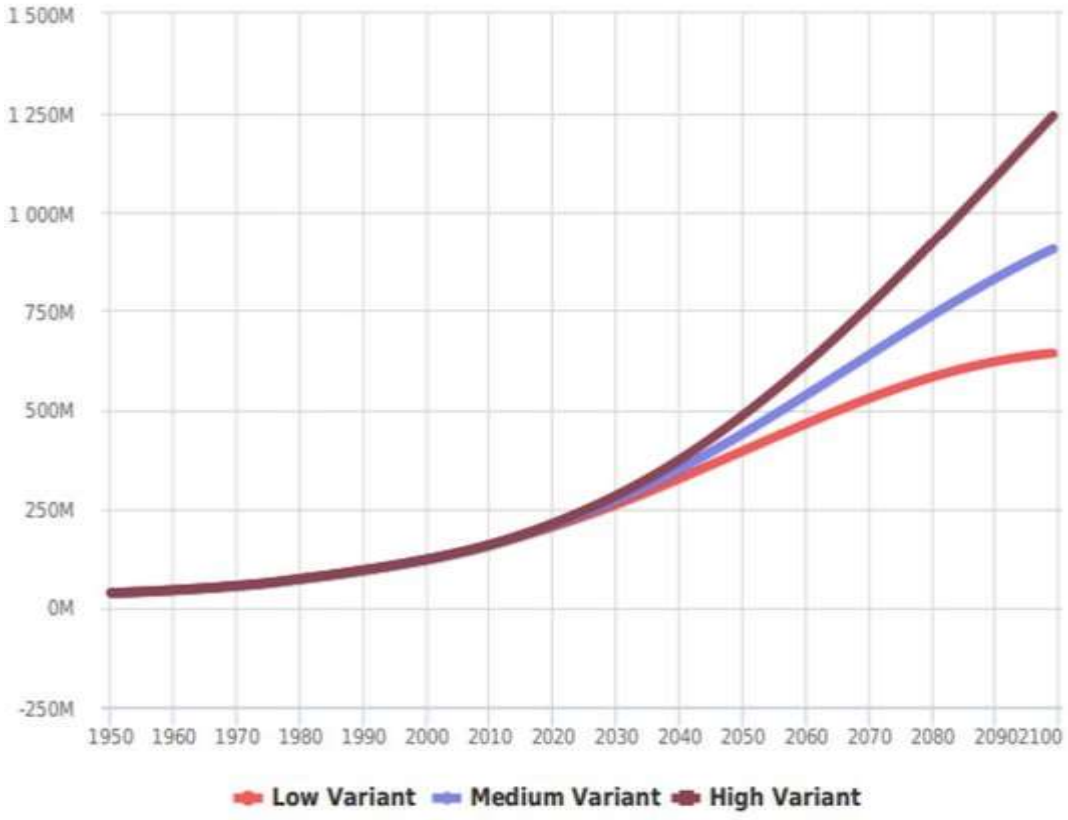


Figure 4.3: Nigeria population projection
(Source: World Population Review 2014)

The rapid growth in Nigeria has not been accompanied by an adequate increase in water service delivery facilities. Analysis of Figures 4.2 and 4.3 indicates that there can be serious implications for the country's ability to meet present and future drinking water demands. These will require making adequate investment in water facilities at all levels (WSP, 2011). From the foregoing, it is clear that the majority of the population may likely experience critical drinking water supply challenges in the near future.

4.2.3 Water resources in Nigeria

It is estimated that the country has about 267 billion cubic metres of surface water and about 52 billion cubic metres of groundwater (USAID, 2010). In the southern part of the country, where rainfall is high, surface water and springs are often the most appropriate source of water, particularly where groundwater aquifers are deep. According to Adelana et al (2008) Nigeria is faced with increasing demands for water resources due to high population growth rate and groundwater resources are used insubstantially in meeting that need (See Figures 4.2 and 4.3). Table 4.1 is an indication of groundwater exploitation in each of eight hydrological areas. The importance of ground water resources and it potential in rural water supply in Nigeria will be further explored in this thesis.

Table 4.1 Distribution of ground water resources in Nigeria (Source: www.unep.org, 2014)

Hydrological Area (HA)	Groundwater Resources (m^3)	Present		Towards Year 2020	
		Demand (m^3)	Water Use Rate (%)	Demand (m^3)	Water Use Rate (%)
North West- I	4,340	20	0.4	290	7
Central West- II	8,180	20	0.2	260	3
Central East- III	6,990	15	0.2	300	4
IV	4,390	5	0.1	180	4
South East- V	7,150	30	0.4	730	10
South West- VI	9,020	70	0.8	830	9
VII	6,280	40	0.7	710	12
North East- VIII	5,580	60	1.0	620	11
TOTAL	51,930	260	0.5	3,920	8

* m^3 express in millions

4.3 Water supply policy development in Nigeria

Over the past decades, there have been various concerted efforts aimed at meeting basic water supply requirements of Nigeria. Despite these initiatives, it is estimated that a considerable percentage of the Nigerian population still lack minimum access to potable drinking water supply, improved sanitation and Hygiene (WSP,2011). For more than half a century, water supply policies have evolved. Table 4.2 shows water supply policy development in Nigeria, and Figure 4.4 illustrates institutional roles and relationships in the Nigeria water sector.

Some policies and key provision are summarised in the Table 4.3. Nigeria is also a signatory to various international conventions and agreements targeted at ensuring increased access and coverage and sustainability of water supplies in Nigeria. (See Box 4.1). However, despite agreed these milestones, institutional policies and conventions the country has not attained universal coverage of water supply. More worrisome is the spate of breakdown and non-functional facilities spread across the country which are a course for serious concern.

Table 4.2 Key milestone in the Nigerian water sector developments

(Source: WSP, 2011)

Year	Event
Early C20th	Public water supply commences in a few towns managed at the lowest administrative level. Amongst the early beneficiaries are Lagos, Calabar, Kano, Ibadan, Abeokuta, Ijebu Ode (Ogun state), and Enugu. Schemes maintained with revenue from water sales with virtually no operational subvention from government
1950s	Financial and technical responsibilities for developing new water schemes assumed by regional governments
1966	First water corporation formed in the Western Region in 1966 to take over assets and liabilities, and existing staff. Staff of Water Division, Ministry of Works transferred to new corporation
1970s	Formation of water corporations spreads to all 36 states and the Federal Capital Territory, with water boards/corporations or public utilities managing their water supply
1979+	Agricultural Development Programs (ADPs) rolled out in many states with rural water supply components as a means of improving the lives of farmers
1976	Federal Ministry of Water Resources and 11 River Basin Development Authorities (RBDAs) created. RBDAs to provide bulk water for irrigation, drinking water supply, among others
1993	Water Decree 101, the principle legislation governing the utilization and pollution control of the water resources
2000-06	Preparation of key policy and strategy documents, guidelines, model laws including: National Water and Sanitation Policy (2000), National Water Policy (2004), National Water Sanitation Policy (2006), National Water Resources Strategy (2006), Draft National Water Bill, WIMAG

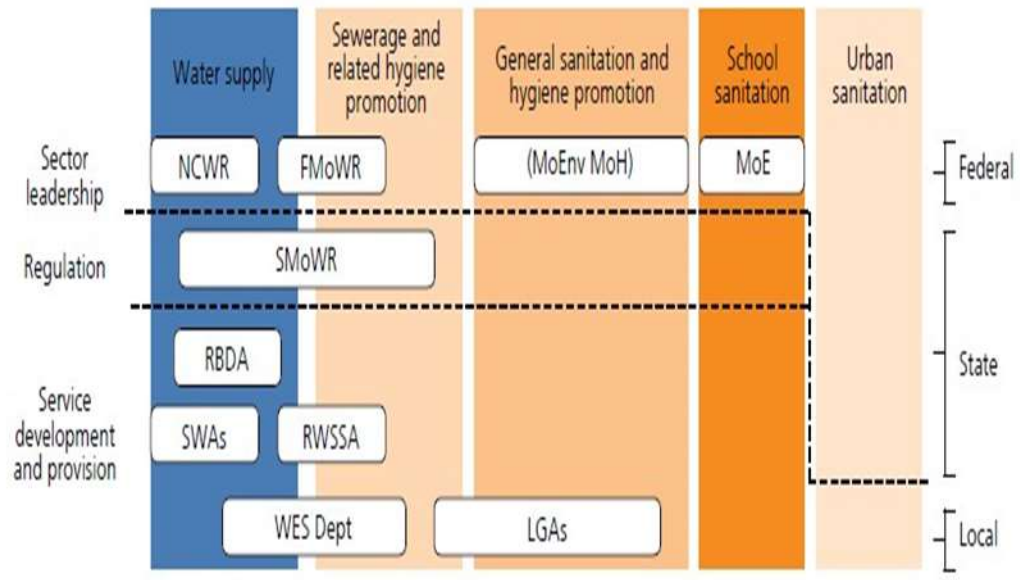


Figure 4.4: Institutional roles and relationships in the Nigeria water sector (Source: World Bank/WSA, 2011)

Table 4.3 Summary of relevant water supply policies (Source: Akpabio 2012)

Policy title	Key provision
National Policy on Environment, 1989	Focuses on water quality regulation and standard as well as pollution control
National Rural Water Supply and Sanitation Policy, 2000	Focuses specifically on rural water and sanitation through community participation. The programme targets were to increase water coverage from 43% to 80 % by 2010 and 100% by 2015. The sanitation coverage was to be increased from 32 % to 60 % by 2010 and 90 % by 2015
National Water Resources Management Policy, 2003	Recognizes water as an economic good, opted for integrated and demand-driven services.
National Water and Sanitation Policy, 2004	Operated strictly in line with the demand-driven approach of the National Water Resources Policy
National Environmental Sanitation Policy (NESP), 2005	Completely touches on a range of issues including solid waste, medical waste, excreta waste, sewage management, food sanitation and hygiene, sanitation at public places, adequate potable water supply, urban drainage management and hygiene education etc.
National Economic Empowerment and Development Strategy NEEDS (2003-2007)	Addressed water and sanitation issues in clearly defined spatial units namely, urban areas, small towns, rural areas. NEEDS placed high priority on the development of safe and adequate water supply and sanitation services as a key instrument for fighting poverty and accelerating socio-economic development
National Development Plan (NDP), 2007	One of the seven-point development agenda of the President between 2007 - 2011administration, with targeted subsidies on water and sanitation facilities planned for the poor

Box 4.1 Human right to water and sanitation

Nigeria has recognized the human right to safe drinking water and sanitation on several occasions. Nigeria voted in favour of General Assembly resolution 64/292 of July 2010 which recognizes the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights. Nigeria co-sponsored Human Rights Council resolution 24/18 of September 2013 and 27/7 of September 2014 and was a member of the Human Rights Council when it adopted without a vote resolution 15/9 of September 2010 and resolution 18/1 of September 2011 and when it co-sponsored resolution 21/2 of September 2012. Nigeria also co-sponsored General Assembly resolution 68/157 of December 2013, adopted without a vote.

Except for the General Assembly resolution 64/292, these resolutions affirm that the human right to safe drinking water and sanitation is derived from the right to an adequate standard of living. Nigeria thereby affirmed that the right to an adequate standard of living includes the human right to safe drinking water and sanitation. The right to an adequate standard of living is enshrined in human rights instruments such as the International Covenant on Economic, Social and Cultural Rights (ICESCR), the Convention on the Rights of the Child (CRC) and the Convention on the Rights of Persons with Disabilities (CRPD).

Human Rights Council resolutions 24/18 of September 2013 and 27/7 of September 2014 furthermore contain a full definition of the human right to safe drinking water and sanitation. Human Rights Council resolution 27/7 of September 2014 reaffirms in preambular paragraph 21 that the human right to safe drinking water and sanitation entitles everyone, without discrimination, to have access to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use and to have physical and affordable access to sanitation, in all spheres of life, that is safe, hygienic, secure, socially and culturally acceptable and that provides privacy and ensures dignity. Nigeria thereby recognized all the content categories of the right as developed by the Committee on Economic, Social and Cultural Rights and the Special Rapporteur on the human right to safe drinking water and sanitation.

In the Abuja Declaration adopted at the First Africa-South America Summit (ASA) in Abuja, Nigeria, in November 2006, Nigeria, along with 64 other African and South American States committed to promote the right of our citizens to have access to clean and safe water and sanitation within our respective jurisdictions. At the 5th World Water Forum in March 2009, Nigeria signed, along with 25 other countries, a declaration recognised that access to water and sanitation is a human right and the country that committed to all necessary actions for the progressive implementation of this right.

(Source: Amnesty International, 2015)

4.4 Water supply institutional structure in Nigeria

This section briefly highlights major institutions in the Nigerian water supply sector at Federal, State and Local government level. These institutions are the NCWR, FMoWR, NWRI, RBDAs, SMoWRs, SWA, RWSSA, WES, ESA, LGAs, WESCOMs, CBOs and the private sector.

4.4.1 National Council on Water Resources (NCWR)

The NCWR was established in 1980. It is the highest water resources policy formulating body in Nigeria, chaired by the Honourable Minister of Water Resources. The council membership includes representatives from the Federal Ministry of Environment, States Commissioners responsible for Water Resources matters and Chairman of the Federal Capital Territory (FCT) water resources agency, (Okoye and Achakpa,2007)

4.4.2 Federal Ministry of Water Resources (FMoWR)

The ministry is responsible for policy formulation, data collation, resources and demand surveys, monitoring, evaluation and coordination of water supply development and management, research and development, national funding and technical support, and the creation of an enabling environment for meaningful private sector participation among others (WaterAid, 2006). Figure 4.5 shows the ministerial and operational organogram of the FMoWR.

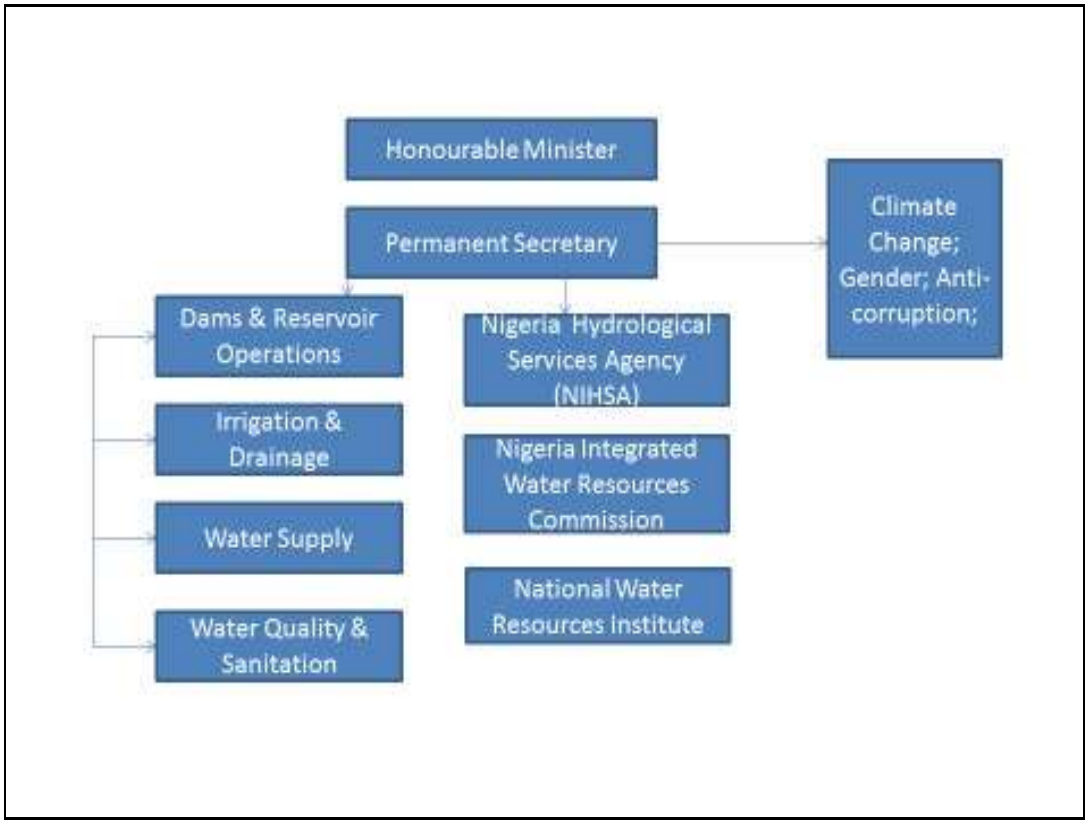


Figure 4.5: Organogram of the Federal Ministry of Water Resources (Source: Ministry of Water Resources, 2014)

4.4.3 National Water Resources Institute (NWRI)

NWRI is the institute designated to provide training and education, data collection and dissemination services in the field of water resources development and management.

4.4.4 River Basin Development Authorities/Boards (RBDAs)

The RBDA is the body charged with the development, operation, and management of reservoirs in their catchment area and provide bulk water supply for water utilities and irrigation. There are twelve RBDA corresponding to the main water basins in the country (Olawale, 2012). Their

main functions include: comprehensive development of surface and underground water resources for multipurpose use, provision of infrastructure for irrigation, flood and erosion control, watershed management and to maintain comprehensive up-to date water resources master plan to foster socioeconomic development and environmental conservation.

4.4.5 State Ministries responsible for Water Resources (SMoWRs)

The SMoWRs are responsible for the drinking water supply at state level. In some states these ministries have been engaged in actual implementation of projects contrary to the policy intentions to keep ministries to policy, regulation, and monitoring mandates.

4.4.6 State Water Agencies or Boards (SWAs)

The state water supply agencies are responsible for the establishment, operation, quality control and maintenance of urban and semi-urban water supply systems. They are also responsible for licensing and monitoring private water supply, water quality monitoring as well as provide technical assistance to local governments. There are 37 SWAs in the country – one for each State and one in the Federal Capitol Territory. SWAs are intended to be autonomous and self-accounting, but they often find it difficult to be operationally and financially autonomous from the State government (USAID, 2010).

4.4.7 Rural Water Supply and Sanitation Agencies (RWSSAs)

The RWSSAs are responsible for the provision of potable water to rural communities and improving sanitation and hygiene Intended roles are facilitation and support to LGAs to implement water programs.

4.4.8 Water and Environmental Sanitation (WES) Departments

Established within local governments structures to oversee the delivery of water and sanitation services, and provide support to communities in the management of facilities, sanitation promotion, and hygiene education. However, it is not very clear how effective the WES departments have been over the years of their role in supporting effective community management of water facilities. This research intends to contribute to this knowledge gap.

4.4.9 External Support Agencies (ESA)

ESAs often partner with state and non-governmental organisations to build capacity to deliver water supply services to rural communities. ESA's

have been actively involved at various scales and levels in Nigeria among others include the following: UNICEF, Japanese International Cooperation Agency (JICA), United Nations Development Project (UNDP), European Union (EU), Department for International Development (DFID), WaterAid, United State Agency for International Development (USAID), World Health Organization(WHO), World Bank, Africa Development Bank (ADB), Save the Children UK and Action Against Hunger and others.

4.4.10. Local Government Areas (LGAs)

Local governments are responsible for the establishment, operation and maintenance of rural water supply schemes in conjunction with the benefiting communities. They also have the responsibility to establish, equip and fund local governments Water and Environmental Sanitation (WES) departments. Bosworth (1993) rightly stated that "As one of the leading

agencies working to protect the quality of the local environment, and as the level of government closest to the citizen, local authorities have a vital role to play in delivering sustainable development".

4.4.11. Water and Environmental Sanitation Committees (WESCOMS)

WESCOMs are community-based water facilities management units. They are responsible for the management of water and sanitation facilities in the community.

4.4.12. Community Based Organizations (CBO)

CBO are indigenous nongovernmental organizations based in project community. They play a very crucial role in the community mobilization, programmes implementation, operation and maintenance, training of communities and local government officials, hygiene promotion as well as policy and advocacy. However, CBO may find it difficult to raise operational fund locally, therefore, many rely on external funding to carry out their functions.

4.4.13. Private Sector

Carter and Danert (2003) state that the private sector has always had an important role in the supply of goods and services, and in consultancy, supervision, and capacity-building. Ssozi and Danert (2012) stated that the private sector undertakes contracts with respective local, state or federal governments, for the supply of goods and services, design and construction of water facilities. Private companies supply spare parts for hand pumps, and private hand pump

mechanics and scheme attendants provide maintenance services to the communities (WSP, 2011).

4.5 Drinking water supply in Nigeria

Households are considered to have basic drinking water service when they use water from an improved source with a total collection time of 30 minutes or less for a roundtrip including queuing. And drinking water is defined as water used, intended to be use, by humans for drinking, cooking, food preparation, personal hygiene and other essential domestic purposes. (JMP, 2015). Table 4.4 shows list of improved and unimproved sources of water based on National Water Supply and Sanitation Programme classification. Analysis of access and coverage in subsequent sections will be discussed and it implication for sustainable water supply in Nigeria.

Table 4.4 Classification of improved and unimproved water facilities (Source: NWSSP, 2001).

Water Supply	
Improved Water Supply	Unimproved Water Supply
• Household Connections • Public standpipes • Borehole (motorized and hand pump) • Protected dug well • Protected spring and • Rainwater harvesting	• Unprotected well • Unprotected spring • Vendor-provided water • Tanker- provided water • Streams and ponds

4.5.1. Rural water supply

Rural communities in Nigeria are settlements having a population of less than 5000, usually lacking basic infrastructure. Water supply in rural area is describe as having access to minimum of 30 litres per capita per day of safe drinking water within 250m of a community, serving about 250 – 500 persons (NWSSP, 2001). The objective of improved rural water supply is the provision of portable water on continuous basis, to ensure that health and poverty alleviation benefits are sustained. Figure 4.6 shows children collecting water from a handpump borehole in Dass community.

In many rural communities in Nigeria water is subsidized and provided to the population free of charge. Local governments are responsible for rural water service, sharing the costs of service with small town water agencies and the federal government when possible. it was argued that main role of the higher government agencies should be to establish institutional rules, regulations, and processes that encourage such local decisions (UNDO-World Bank, 1995).

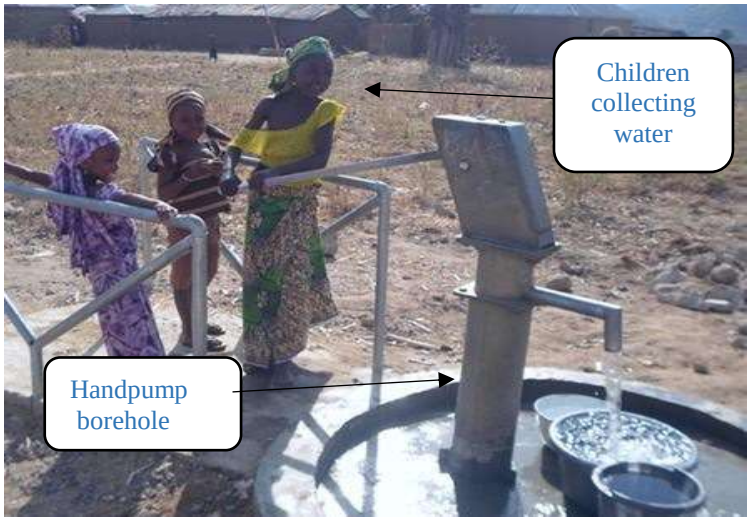


Figure 4.6: Children fetching water from a borehole in Dass

Nwankwoala (2011) was of the opinion, that rural water and sanitation in Nigeria suffered from poor co-ordination, poor maintenance culture, poor technical/institutional structure, multiple programmes, lack of data/information for planning, over bearing bureaucratic control by various supervising ministries, lack of professional inputs on projects, lack of community participation and inadequate funding as well as, inappropriate technology and lack of adequate monitoring and evaluation.

The challenge is not peculiar to rural Nigeria. Across the entire sub-Saharan Africa region since 2000, almost a quarter of the population have gained access to an improved drinking water source. This translate to an average of over 50 000 people per day, every day, for 12 years in a row. However, in the same region there is an estimated non-functionality rate of 40-50% (RWSN, 2009). Therefore, the high level of breakdown, and non-functioning system indicates a need to explore other sustainable options to safeguard investments in water facilities in the region.

Figure 4.7 shows a significant difference between improved drinking water coverage between 1990 and 2015 in rural Nigeria. Total improved coverage was 25% and 57% respectively. However, a closer look at the data shows on that contrary to the overall general rise in coverage, there is a decline in percentage of the rural dwellers accessing water on premises from 3% to 1% within the period and similarly a decline in surface water supply.

Therefore, groundwater sources account for more than 80% in the form of boreholes and hand-dug wells. With about 50% of handpump break down in Nigeria, it is arguable that the estimated coverage may not even represent the actual reality on ground due to service failure. Hence, the

use of groundwater to meet water demand does require careful consideration as well as the impact of broken-down and abandoned boreholes.

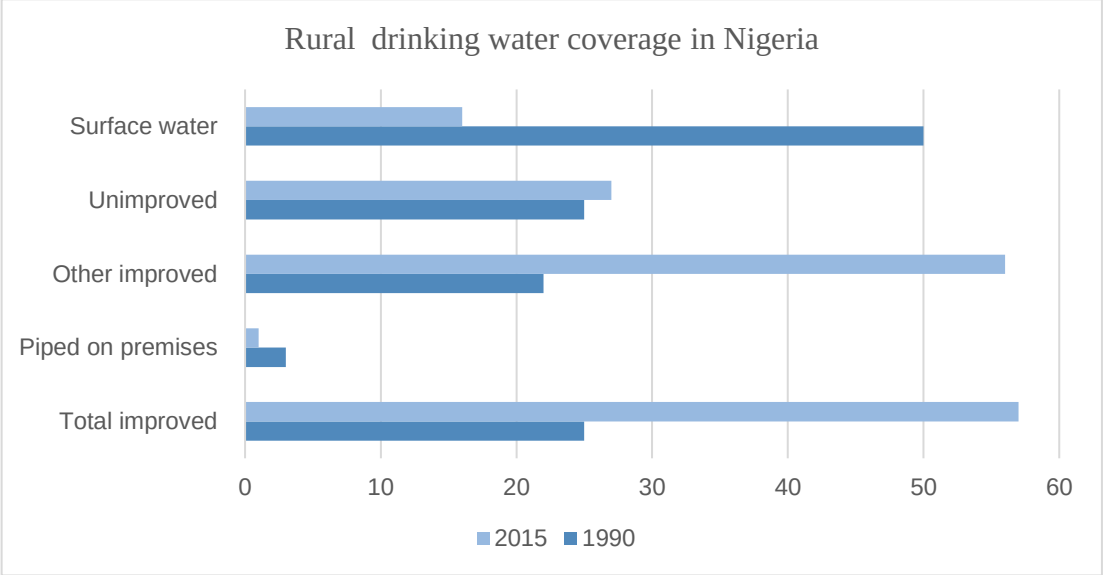


Figure 4.7: Rural drinking water coverage in Nigeria (Source: JMP, 2015)

4.5.2 Small Towns water supply

Small town or semi-urban communities in Nigeria are classified as settlement having population between 5000 – 20000, some social infrastructure and a significant amount of economic activities having a minimum water supply is 60 litres per capita per day (NWSSP, 2001). The main source of drinking water supply usually consists of, but not limited to, mechanised borehole facilities connected to an overhead tank serving a standpipe or distributed through a pipe network (see Figure 4.8 showing a generator house, overhead tank and borehole site). Water is usually pumped from a submersible pump borehole into an elevated reservoir. Water in the tank is transmitted through a pipe network to a standpipe or directly connected to

households. Individual households may have limited or full connections depending on water supply capacity, design or local arrangement.

The main sources of income for populations in these areas is small scale trade followed by peasant farming and a few, generally agro-based, industries. Small towns attract people from rural areas, and tend to be diverse, dynamic and constantly evolving environments. The presence of schools, health and administrative centres may attract further in-migration (WaterAid/BPD, 2010). In many small-town communities as fringe areas tend to be more rural in nature, with mainly residential houses widely spaced from each other compared to the core.

Figure 4.8: Small town water supply scheme

Adank (2013) is of the opinion that, in the future, small towns will grow in number, population and importance. Therefore, improving understanding on how sustainable water services can be provided in small towns is therefore likely to remain high, or even rise on the water sector

agenda in the years to come. Small town and semi urban communities are of interest to sustainable water facilities research because demand for sustainable water supply sources will be higher in small towns than in rural communities but less than in urban communities.

Due to rapid population growth, many rural communities will in a few years become small town, or semi-urban settlements. The capacity to sustainably manage available water supply service in these communities requires in-depth investigation. Small town drinking water supply arrangement is very similar to rural in the sense that, they use on site water sources such as borehole facilities, the main difference is the population and scale of the number of people using the water source. Also, there tend to be more considerable private water vendors in small town than rural.

Braimah (2010) stated that the main challenge hindering small town water schemes operators to deliver sustainable services is low revenues high, costs of operation and the availability of alternative albeit unsustainable water sources.

4.5.3 Urban water supply

In Nigeria, urban settlements are communities with population of over 20000 people. Water supply in urban water supply is 120 litres per capita per day (NWSSP, 2001). Unlike rural and small towns, urban water is often served by piping into premises. The country's rapid urbanization and growth rate has however not been accompanied by an adequate increase in water facilities (USAID, 2010). Therefore, the urban water sector has declined in piped into premises water supply from 32% in 1990 to about 3% in 2015 (See figure 4.9).

There is significant difference in overall access within the period but the point to note is that other improved sources shows significant change from 44% to 78% in urban areas. Just like in the rural areas a sizeable percentage of Nigerian in urban centres resort to ground water resources such in hand dug wells and mechanised boreholes. Again, there is an argument for the careful consideration of the number on individual boreholes drilled and wells dug to meet this need and how sustainable the approach can be for water resources and environmental sustainability.

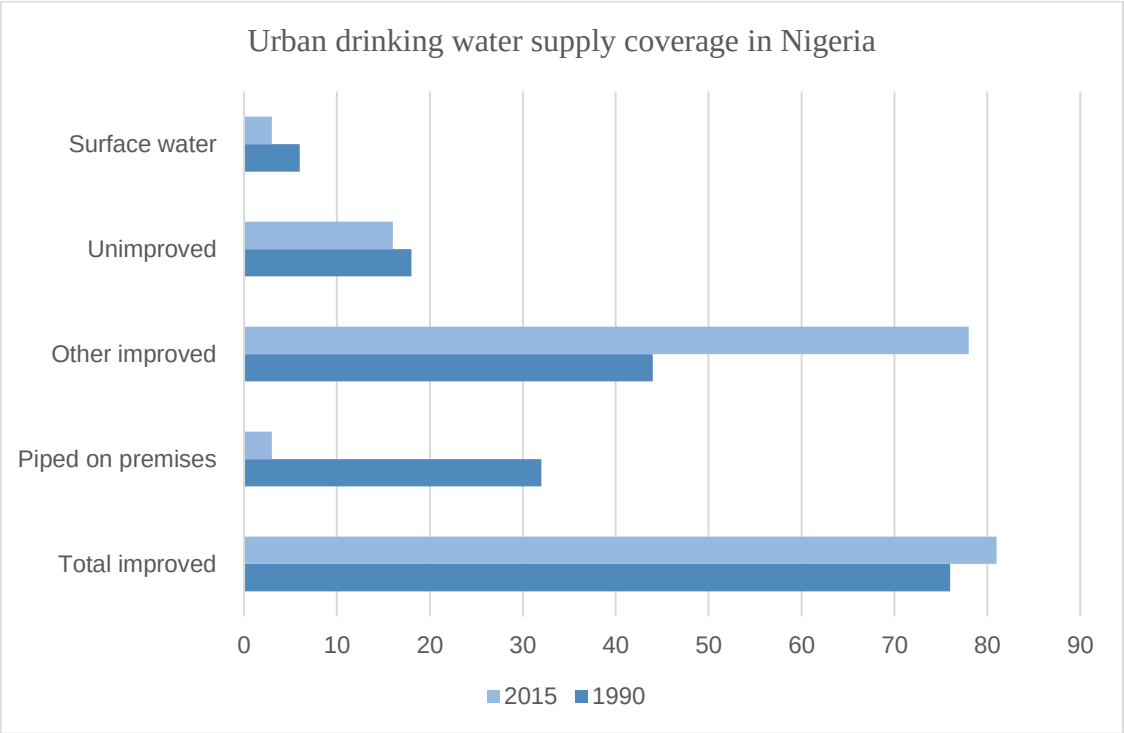


Figure 4.9: Urban drinking water supply coverage in Nigeria (Source: JMP 2015)

In research carried out by WaterAid (2011) on water supply in urban areas, some of the core challenges facing many urban water utilities around the world were particularly in Asia and sub-Saharan Africa. These include:

- Under-investment due to lack of stable, predictable and sufficient finance;
- High population growth in urban areas without proportionate expansion in the service of utilities;
- Public utilities being treated as social services;
- Insufficient operational and management autonomy from government;
- Poor management with no regulatory mechanisms to monitor public utilities or making them accountable for performance; and
- Inefficiency whereby government is often forced to functionally 'prop up' failing and bankrupt utilities. The utilities cannot expand to serve new customers and may use state funds inefficiently to serve existing ones, almost always the non-poor.

4.6 Overall drinking water supply coverage in Nigeria

As shown in Figure 4.10 the percentage of population use of improved drinking water sources has risen from 40% in 1990 to 69% in 2015. Population using unimproved sources has not declined much. Surface water remains the same at about 50%. The number people now accessing other improved sources has almost double. However, piped on premises supply has declined from 12% to 2% (See Figure 4.10).

In Nigeria overall, only 48% of the proportion of the 2015 population have gained access since 1990. From the foregoing, it is clear that the increase in coverage is to a large extent dependant on other sources such handdug wells and boreholes exploiting ground water. Therefore, beyond the sustainability of facilities is the need to considered water sources and environmental sustainability of water resources.

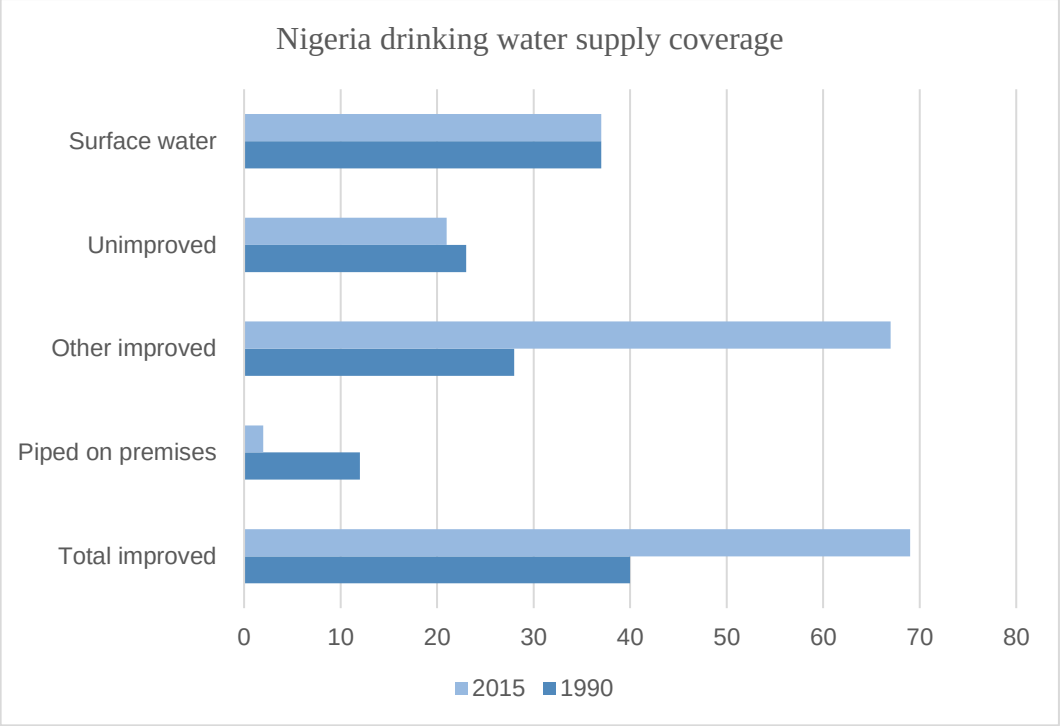


Figure 4.10: Nigeria drinking water coverage
(Source: JMP, 2015)

The data analysed in the sections above represent recent update on drinking water coverage in Nigeria. However, it is critical to note that the level of coverage do not usually account for non-functioning facilities reported at national, regional or global level. Hence, many communities and individual household continue to lack access locally.

4.7 The need for sustainable water service delivery in Nigeria

As earlier stated, despite the investments at various levels, the government of Nigeria has failed to successfully deliver sustainable and equitable access to safe, adequate, improved and affordable water supply to most the population over the years. Water has been recognised to be vital health importance as discussed in chapter 2. Nigeria has the lowest life expectancy of around 47 years of age for adults in West Africa. This has been attributed to lot of health issues

in the country, principally because of lack of access to safe drinking water, improved sanitation and hygiene (AfDB, OECD, UNDP, 2014). One out of every five children born in Nigeria may die before reaching the age of five due to the many health risks (World Population Review, 2014). Also, the country is one of five countries in the world which together accounts for half of under-five deaths, with Nigeria at 13% (World Bank, 2013). Therefore, sustainable water supply would improve health and social wellbeing in the country.

Another important factor is high population growth in Nigeria, which results in an increasing demand against a diminishing trend in supply thereby creating a large supply gap, particularly in the small town and urban areas. Reasons for the limited progress towards universal access to an adequate water supply include high population growth rates in developing countries, insufficient rates of capital investment, difficulties in appropriately developing local water resources, and the ineffectiveness of institutions mandated to manage water supplies (in urban areas) or to support community management (in rural areas) (Hunter et al.,2010). Also, high population growth has been associated with lower sustainability due to wear and tear on water facilities (Akanbang et al., 2008, Davis et al. 2008).

Table 4.5 shows an estimated Capital Expenditure (CAPEX) required to deliver water and sanitation services to millions of people anticipated to require access up to 2015. It shows a deficit of total $839 million per year, indicating inadequate resources to deliver the needed coverage. This situation limits resources for rehabilitation or repair of existing facilities, which supports the argument for more sustainable water service delivery option that have potential to expand coverage as well keep existing services functional. The table also shows no figures for Household(HH)-Capital Expenditure (CAPEX), which may support argument that private self-

supplied water facilities is widely recognised within the water sector in Nigeria and many sub Saharan African country.

Table 4.5 Nigeria water supply coverage and investment requirements

(Source: WSP 2011)

Water supply	coverage		Target 2015	Population requiring access	CAPEX requirements		Anticipated public CAPEX			Assumed HH CAPEX	Total deficit
	1990	2008			Total	Public	Domestic	External	Total		
	%	%	%	000/year	US$million/year						
Rural	30	42	69	4569	604	604	350	84	434	0	170
Urban	79	75	95	4927	1113	1113	350	94	444	0	669
Total	**47**	**58**	**82**	**9507**	**1716**	**1716**	**700**	**178**	**878**	**0**	**839**

Carter et al, (1999) lists four reasons why sustainable water services are important which also applicable in Nigeria as follows:

(i) **Loss of investment**: facilities intervention requires huge investment in human, material and financial resources. If its beneficial impact is not sustained over a long period, it cannot be deemed cost-effective. Funds invested by users and by donors go down the drain. Where services are functioning, other available funds serve to increase coverage. Figure 4.11 shows DFID-WASH sector intervention achievement in some developing countries including Nigeria. The figure shows that about 5.1 million people were reach with one or more water, sanitation or hygiene promotion interventions. Except these interventions are sustainable, investment would be lost.

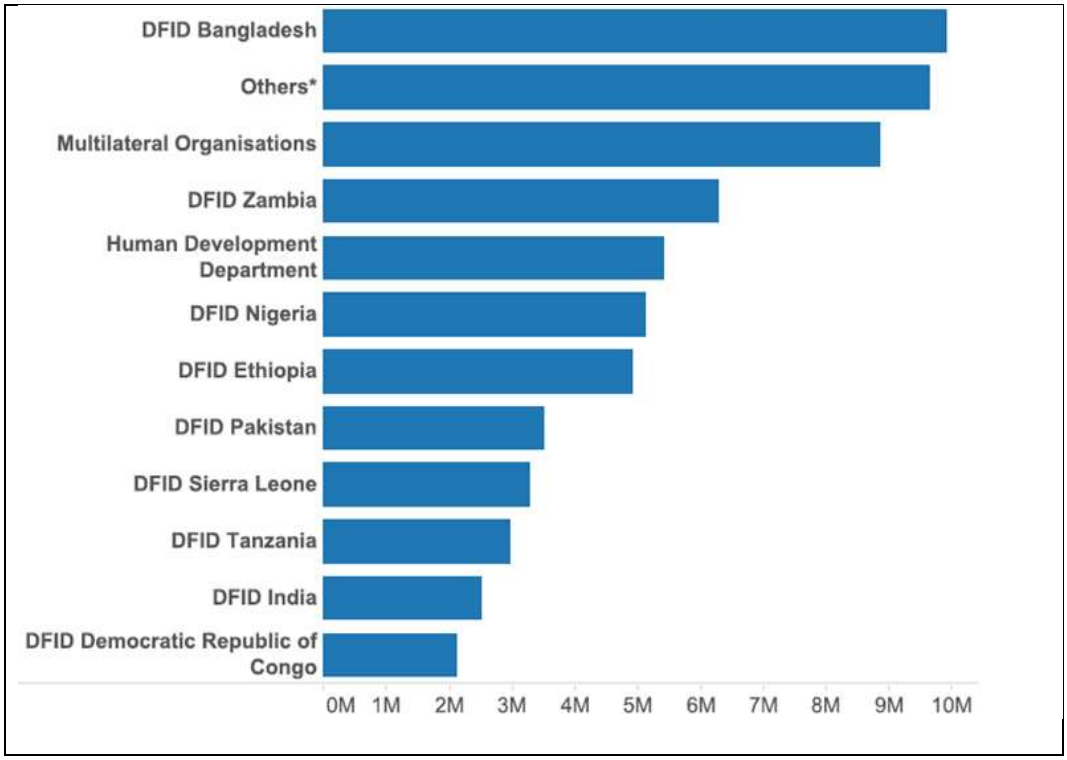


Figure 4.11: DFID-WASH sector achievement
(Source: DFID, 2016)

(ii) **Decelerates progress:** where services are not sustainable, progress towards achieving service coverage targets towards the Millennium Development Goals (MDGs), and more recently the Sustainable Development Goal (SDGs) is undermined by non-sustainable interventions. If services are falling into disrepair as others are being newly constructed, the net progress toward full coverage decelerates – the antithesis of the drive toward scaling-up of service delivery.

(iii) **Demotivate stakeholders drive towards improved coverage:** non-sustainable interventions serve to discourage the households, communities and local

government/NGO institutions which have seen some short-term benefit, only to be disappointed as hard-won gains are snatched away.

(iv) **Build confidence and self-esteem:** Sustainable services build confidence and increase self-esteem among communities, supporting institutions, and possibilities for further self-help or locally initiated undertakings, creating a multiplicative effect as well as scaling up successful service delivery models (Adapted from Carter et al, 1999)

4.7.1 Cost implications of water supply and sanitation in Nigeria

A desk study carried out on economic impacts of poor sanitation in Africa reveals that poor sanitation costs the country about $2.5 billion each year, equivalent to 1.3% of the national GDP (WSP, 2012) The cost is further enumerated as follows:

(i) **Wasted time:** Each person practicing open defecation spends almost 2.5 days a year finding a private location to defecate leading to large economic losses. This cost falls disproportionately on women as caregivers who may spend additional time accompanying young children or sick or elderly relatives. This cost is likely to be an underestimation as those without toilets, particularly women, will be obliged to find a private location for urination as well.

(ii) **Premature death:** $2.5 billion is lost each year due to premature death. Approximately 121,800 Nigerians, including 87,100 children under 5, die each year from diarrhoea, about 90% of which is directly attributed to poor water, sanitation and hygiene.

(iii) **Productivity loss:** $13 million is estimated to be lost each year due to productivity losses whilst sick or accessing healthcare. This includes time absent from work or school due to diarrhoea, seeking treatment from a health clinic or hospital, and time spent caring for under-5 suffering from diarrhoea or other sanitation-attributable diseases.

(iv) **Health care loss:** It is estimated that $191 million is spent each year on health care to treat diarrhoeal directly, and indirectly via malnutrition which are all leading causes of morbidity. Costs are associated with health seeking behaviour include consultation, medication, and transport and in some cases hospitalization, which places a heavy burden on households and government spending.

(v) **Other losses:** The study also identifies other additional costs that are likely to be significant, but they are more difficult and expensive to estimate, and therefore have not been precisely valued, such as epidemic outbreak cost, funeral costs, water pollution costs, cognitive development in children costs, costs lost in tourism potential and losses from re-use or recycling potential. This has been estimated to cost Nigeria about $3 billion annually.

4.8 Barriers to sustainable water service delivery in Nigeria

According to National Planning Commission (2011) the main challenges to delivering sustainable water supply and sanitation in Nigeria specifically include:

- Lack of appropriate policy, legal, regulatory and institutional framework;
- Poor community and private sector participation in terms of operation, management and maintenance in water supply and sanitation services;
- Weak managerial and executive capacity, total lack of coordination at the state and local government levels;
- Low investment level in operation and maintenance which accounts for frequent breakdown of distribution facilities;
- Epileptic power supply;
- The colossal unaccounted-for water in terms of losses, leakage or unbilled in urban water systems;
- Failure to appreciate that water is a finite resource and an economic and environmental good for which a realistic tariff should be charged to recover at least operational and maintenance costs; and inappropriate pricing and tariff collection mechanisms for water supply and sanitation services;
- Inadequate public awareness about water conservation and management for effective sanitation and public health hygiene;
- Poor data collection, collation and archiving, making effective planning, implementation and evaluation very difficult;
- Inadequate awareness about the relationship between sanitation and good health;
- Poor community participation in water supply and sanitation matters, creating the impression that sanitation is government business;
- Lack of appropriate water supply and sanitation facilities/infrastructure in the country;
- Lack of adequate capacity to predict the impact of climate change as it affects rainfall characteristics and variability and other water sources; and

- Increasing rate of urbanization resulting in shortages of water supply and sanitation services in urban and semi urban areas.

4.9. Chapter summary

This chapter presented a general overview of the Nigeria in the context of water resource, water supply coverage and supply. The country profile was reviewed in relation to current high population growth rate, social economic conditions, water resources potentials, and policy environment in from water supply perspectives. Challenges and cost implication for failing to meet drinking water needs in Nigeria were highlighted. However, a key knowledge is the lack of acknowledgment of the potential in private individual and household to meet their own water. The chapter revealed that despite over five decades of water sector development of policies, institutional structures, roles and responsibilities have not translated into universal coverage in water supply in the country.

Three basic water supply identified include; rural, small town and urban water supply. The small town and urban are beyond the scope of this research. It was found that beyond just lack of facilities is a greater task to operate and maintain existing facilities. The trends and coverage presented in this chapter shows an overall increase in drinking water supply in Nigeria between 1990 and 2015. However, the coverage reported, does not usually account for water facilities that are non-functioning or how sustainable is the water sources. Also, it was also acknowledged that the increased in coverage and access recorded in Nigeria is hugely dependent on ground water sources.

Therefore, the question is on how sustainable are the water facilities and the water sources. For the rural water facilities, it was found that the service delivery and approach, technology and the cost of operation and maintenance are the main factors responsible for lack of sustainability, which form the basis for need for a sustainable approach such as discussed in chapter 5 in subsequent section.

Chapter 5

5.0 Exploring alternative approaches for sustainable water service delivery in Nigeria

5.1 Introduction

This chapter will explore potential for sustainable rural water supply based on the findings from literature discussed in previous chapters. It was established that the inability of communities to operate and maintain water facilities in the long-term and the consequent failure of many systems is the major manifestation of the unsustainable approach currently being practised in Nigeria.

Amongst the five-main underlying sustainable water service delivery drivers such as financial, institutional, environmental, social and technical factors identified in the literature, Chowns, (2014) found that the key proximate determinants of water facility sustainability are technical and financial management issues. However, beyond these two factors, many sustainability concepts reviewed have failed to focus on the aspect of environmental sustainability in respect to groundwater exploitation subsequently, water resource management has not received significant attention under the sustainable water service supply concept. Therefore, this chapter seeks to explore technically, financially and environmentally viable options toward sustainable rural water supply.

5.2 Exploring the concept of Self-Supply

The discussion in chapters 3 highlighted the failure of community-based water facilities to function sustainably. This has informed the focus of this research on the need for individuals

or households to consider to own their water facility to increases their access to improved water service which is recognised in some literature as the concept of self-supply.

The concept of self-supply refers to local level or private initiatives by households to improve their own water supplies, without waiting for help from government or a non-government organisation (Carter, 2006). The idea evolved naturally as people responded to their need for an improved water supply. However, it, has been much constrained by lack of awareness of what can be achieved, inadequate private sector and government advice and services, unaffordable technologies and financial limitations (Sutton, 2009).

Sutton (2004) who advocates the concept self-supply, argued that self-supplied water facilities are easier access to the user, low-cost and much easier to manage. However, in many developing countries including Nigeria, the concept has suffered set back often focus policy makers, practitioners and other professionals in the water sector have often relegated idea to the background. This stem from the notion that the poor quality of water delivered, quality of the facility construction, and the impact of seasonal variation on the reliability of water source such as in the case of hand-dug wells. On the contrary Carter (2006) argued the self-supply can offers improved water quality, an opportunity for an incremental upgrading of water systems. Self-supply has implications for overall water policies, funding, community support networks, replicability.

Sutton (2007) developed four building blocks which are required to create an enabling environment for self-supply illustrated in Figure 5.1 as follows:

(1) Technology options/advice

(2) Financial mechanisms/ markets

(3) Private sector capacity

(4) Enabling policies, which support development of private ownership and enable rural populations to know about options.

Table 5.1 shows difference between conventional communal and self-supply water facilities.

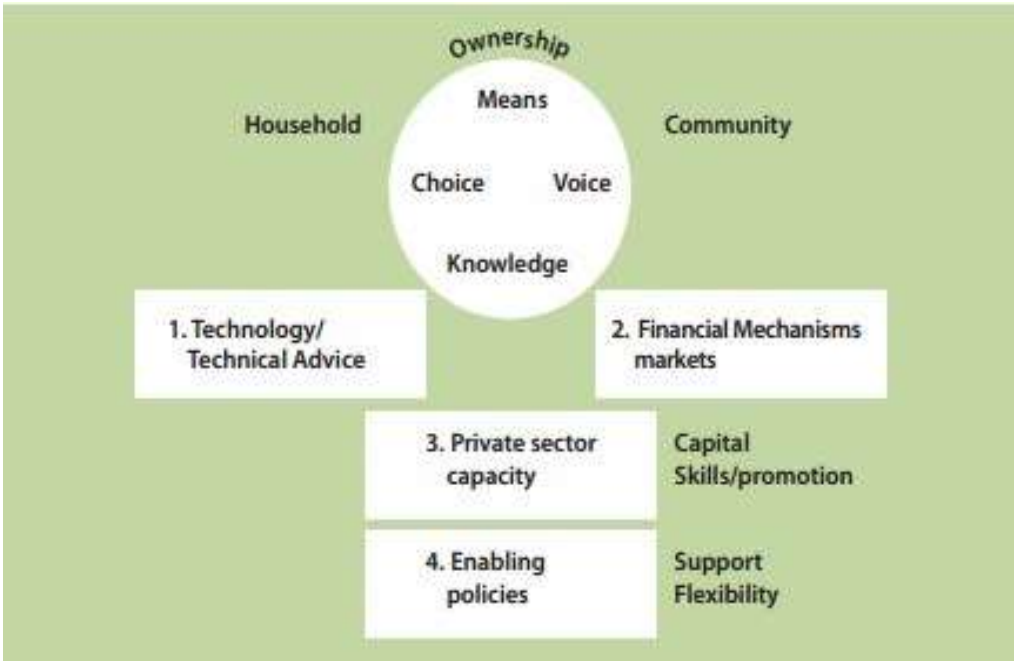


Figure 5.1: Building blocks of an Enabling Environment (Source: Sutton 2007)

Table 5.1: Comparison between communal and self-supply water facilities (Source: Sutton, 2004)

Conventional communal systems	Self-supply system
Best suited to nucleated, homogeneous communities, with good leadership	Suited to individual households and small Groups
Technologies available for wide variety of conditions, greater flexibility in siting	Easily established where water is within 15 meters of surface or rainwater adequate
Focuses on outside knowledge and remote Technologies	Builds on local knowledge, attitudes, and Skills
Serves large numbers of people, who may or may not form a community	Serves households or small groups forming natural management units
Safety and quality of water usually assumed, not always correctly; perceived value among users may be less than assumed	Significant improvements in water quality, comparable to fully protected communal shallow wells but at much reduced cost; high perceived value among users
Generally marketed for health benefits; income generation often difficult because of communal ownership	Often generates multiple benefits including income, improved nutrition, and local employment
Depends on committee management which is not traditional and may take time to develop	Well-defined ownership and management by individual or well-established group
Provides good water within 0.5 to 1 kilometers, but households may have nearer alternative sources	Provides good water, usually within household boundary or within 100 meters
Rapid construction, but construction teams not usually involved in maintenance unless with outside funding	Rapid small changes, slower process to reach final product, construction teams also do maintenance
Long-term maintenance is expensive, requiring heavy equipment and transport	Regular and long-term maintenance can be carried out by local artisans, including progressive re-deepening at low cost
Higher standards from the start but sustainability may be low	Gradual steps towards high standards, each bringing sustainable improvement
Often donor driven	Develops directly from local demand

5.2.1 Potential for self-supply in Nigeria

The potential for self-supply in Nigeria rural water supply is enormous. It is important however, to note that self-supply already exist in Nigeria. Up to about 70% of Nigerians are using privately water sources. However, over 51 million people still lacking access to improved water supply could benefit from self-supply. Figure 4.11 in section 4.6 clearly indicated that there is a decline in pipe on premises water from about 35% in 1990 down to less than 10% in 2015. It also shows an overall rise in other improved sources of water supply, from about 50% in 1990 to about 80% in 2015, which clearly relates to the use of onsite individual water sources in Nigeria. As earlier discussed in chapter 3, population rise and the inability of the government to increase coverage in water supply coverage has led to privately constructed borehole and handdug wells.

Discussion on self -supply so far has shown that the concept is not new to the Nigerian society. However, for reason already discussed, the idea is less prioritised by stakeholders. What is needed is to address the concerns raised about self-supply and explore the environmental viability of self-supplied. Therefore, the question is what can be deployed to address these concerns in technically, financially and environmentally sustainable manner remain a knowledge gap to be explored.

5.3 Exploring Handdug Well (HDW)

National Demographic Health Survey NDHS (2013) survey result indicated that in Nigeria., about 37% of the population use handpump borehole users. However, Handpump boreholes has an estimated breakdown rate of about 50% (see section 4.5.1).

Table 5.2 Drinking water sources in Nigeria
(Source: NDHS 2013)

Characteristic	Population (%)		
Source of drinking water	Urban	Rural	Total
Improved	77.6	47.7	59.6
Piped into premises	6.1	0.8	2.9
Public standpipe	9.6	4.7	6.6
Borehole	45.8	30	36.3
Protected well	13.1	11	11.8
Protected spring	0.3	0.5	0.4
Rainwater	0.8	0.5	0.6
Bottled water	1.2	0.8	0.2
Non-improved	22.2	52.2	40.1
Unprotected well	4.7	26.2	17.6
Unprotected spring	1.2	4.2	3
Tanker/ Cart with truck	3.6	0.6	1.8
Surface water	4.1	20.3	13.9
Sachet water	8.6	0.7	3.8
Other water	0.1	0.1	0.1
Missing	0.2	0.2	0.2
Total	100	100	100

Over 35% the Nigerian population of about 70 million use hand-dug well, the data further revealed that about 18% uses unprotected hand-dug well, while 11% rely on protected wells, (See Table5.2). Overall, over 50 million people in Nigeria use hand-dug well. Individual/household/community effort, as discussed in section 5.2 known as self-supply has

been explored because of failed public water facilities, favourable groundwater potential and a relatively low cost of construction, operation and maintenance. Exploring traditional hand-dug well as a viable technical option could increase coverage and sustained service delivery. Oluwasanya (2009) pointed out that upgrading or improving hand-dug well will benefit, millions of people in Nigeria.

5.3.1 Hand-Dug Wells (HDW)

HDW have been in existence for thousands of years. They are considered the most common traditional method of obtaining groundwater in many rural communities in developing countries. Although mechanised methods are more efficient and effective, limited options are given for communities in need of water supplies particularly in remote rural, deprived and vulnerable communities (Clean-waterfor-laymen, 2015).

MacDonald et al (2015) noted that, in many parts of Africa such as in Nigeria, long dry season and dispersed nature of many of the populations who currently have no reliable water supply mean that the development of groundwater is the only realistic option for significantly improving drinking water coverage. However, the use of HDW has been relegated to the background in favour of handpumps, mechanised boreholes which often fail to continue to deliver services over time.

5.3.2 Components and dimension of HDW

HDW can range in depth from about 5 metres deep, to deep wells over 20 metres deep. Wells with depths of over 30 metres are sometimes constructed to exploit a known aquifer (WaterAid, 2013). It is impractical to excavate a well which is less than a metre in diameter. An excavation of about 1.5 metres in diameter provides adequate working space for the diggers and will allow a final internal diameter of about 1.2 metres after the well has been lined. According to Skinner (2003), a HDW is divided into three main sections as shown in Figure 5.2 namely; Headwork, Impermeable line shaft and the Intake.

- Headworks are designed to reduce the potential for contamination of the well and to make it easy for people to collect water from it
- An impermeable lined shaft to support the soil, and to prevent polluted surface water from seeping into the well
- Intake section: is designed to hold back the soil but allow water to enter the well.

These vital components of HDW are important when assessing the quality of service that could be obtainable from well. For instance, properly constructed wellhead will reduce ease of contamination from external sources. The impermeable lined shaft provides enhance structural integrity for well, particularly in case of loose soil or areas experiencing soil collapse. The intake section provides an impermeable component for water collection. These components form part of the basis for sanitary risk assessment approach discussed in chapter 6 and 7.

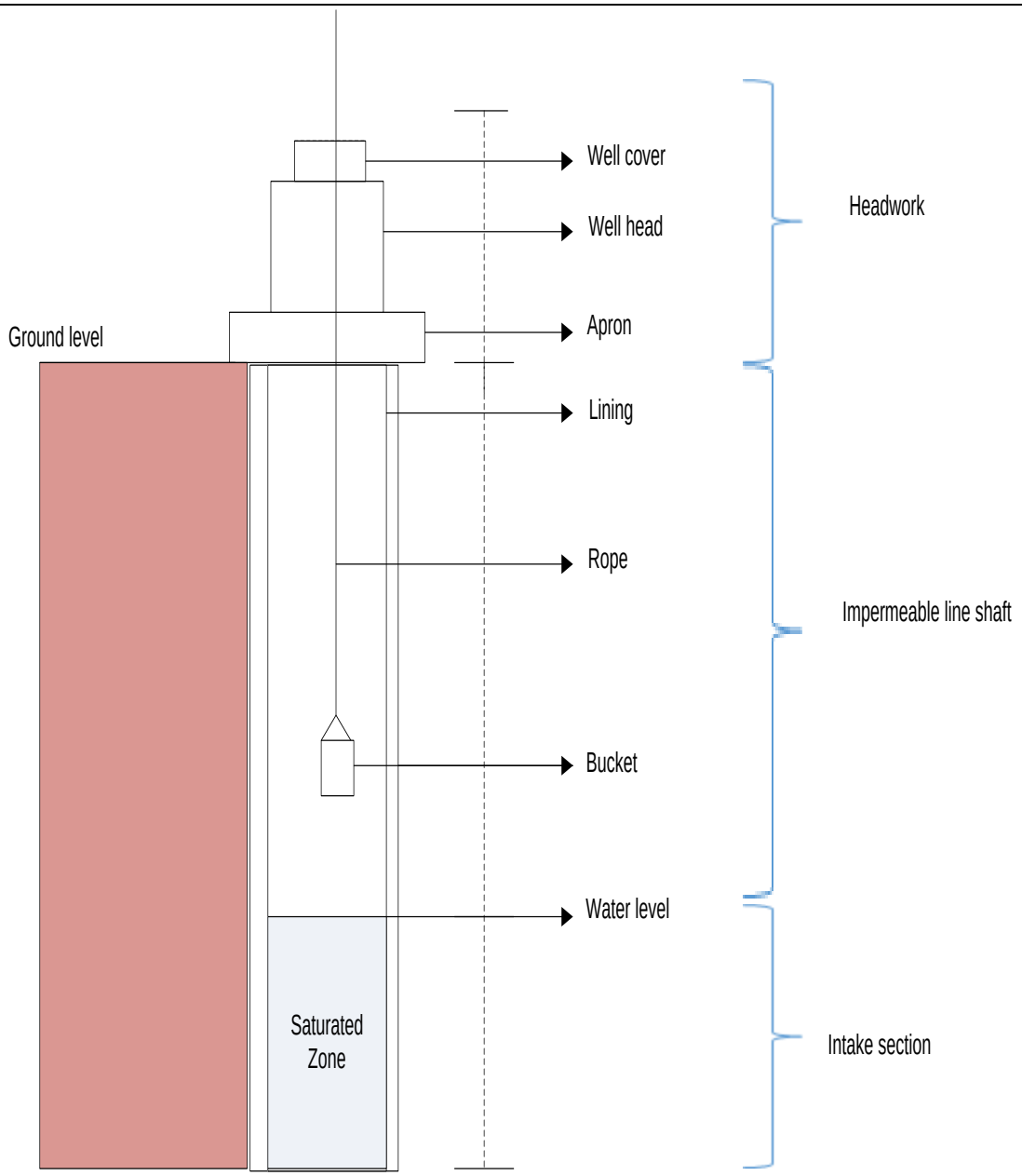


Figure 5.2: Cross-sectional features of HDW
(Source: Oluwasanya, 2009)

5.3.3 Advantage and disadvantages of HDW

According to WaterAid (2013) HDW is the most common traditional method of obtaining groundwater in rural areas. However, their use is restricted to suitable types of ground such as clays, sands, gravels and mixed soils where only small boulders are encountered. Some communities use the skill and knowledge of local well-diggers, but often the excavation is carried out, under supervision, by the villagers themselves. The volume of the water in the well below the standing water table acts as a reservoir which can meet demands on it during the day and should replenish itself during periods when there is no abstraction. Table 5.3 outline some advantages and disadvantages that are associated with the use of HDW. The figure 5.3 shows children drinking from an open unprotected community HDW in Dass Bauchi State Nigeria (see Figure 6.1).

Figure 5.3: Children drinking directly from an open HDW in Dass

Table 5.3 Advantages and disadvantages of HDW
(Source: www. clean-water- for- laymen.com)

Advantages	Disadvantages
Making HDW requires only common tools and skills, so it can be done by anyone.	HDW is very dangerous to make due to the high potential for cave-ins and lack of oxygen. Digging a well is very hard work for one person. Because it is difficult to dig very deep, HDW of more than 30 meters are uncommon.
Many local artisans have specialized in this trade as a business.	Unless the groundwater seeps in very slowly, it is not possible to dig more than about a meter below the water table. Digging into rock is extremely slow.
Where labour costs are low, this is usually the least costly method of well construction.	HDW is very difficult to protect from contamination. There are many ways for surface water to seep in, and the typical bucket on a rope used to fetch water easily transmits bacteria to the groundwater.
In an aquifer with low permeability, a large diameter HDW, may produce more water than a borehole in the same aquifer.	HDW can be protected by sealing the walls, pouring a concrete apron, putting a lid over the top, and installing a hand pump. However, these measures increase the cost of the well.

5.3.4 Operational Barriers of HDW

Environmental conditions: Because of being dug by hand, their use is restricted as previously stated to suitable types of grounds such as clays, sands, gravels and mixed soils where only small boulders are encountered (WaterAid, 2013). Some places with very low water table requiring very deep wells are usually not suitable for HDW. In Nigeria, areas, such as Plateau State with rocky terrain, the problem of soil collapse (Benue state) or even

high water table makes it practically impossible to site a well.

Change seasonality: According to 1CE (2011) wells that are not constructed to sufficient depth to accommodate seasonal fluctuations in groundwater levels or with sufficient storage to accommodate demand will suffer reduced yields due to seasonal variation. During the dry season, particularly in Northern Nigeria, HDW yield is drastically affected by dry weather. Wells falling far below water table tend to dry up completely, users may have to wait for ground water recharge after water has been collected during peak times. In some communities, ground water in HDW is perennial and produces water throughout the year.

Social perceptions: In many parts of Nigeria, unprotected HDW have been a source for many years, however, they are traditionally considered unsuitable for drinking and less preferred to handpumps. They are perceived as unsafe, with boreholes or pipe borne water are considered as of higher quality (WHO, 2012). This notion was corroborated by Oluwasanya (2009) investigation on HDW for self-supply in urban areas of Abeokuta, Nigeria, confirming that the quality of water from HDWs is perceived by users to be poor. Its usage is prioritised for non-drinking purposes. HDW is considered primitive, usually meant for people at lower, societal levels and therefore politicians often advocate for the use of mechanised boreholes as a developmental strategy. Thus, HDW has been relegated to the background as a source of water supply.

Water quality: Water is considered as non-contaminated when it complies with the guideline values for microbial quality i.e. containing zero E. coli or thermotolerant coliforms in a 100-ml sample (Moe and Rheingans, 2006). Several studies conducted on the physio-chemical characteristics of water from HDW have confirmed the presence of E-

coli and coliform beyond and above WHO and NSDWQ guidelines (Chindo et al, 2013).

Open wells can easily be polluted by grounded water if they are close to pit latrines or a soak-away pit, or if there is seepage from surface water, by vessels used for drawing water, if rubbish is thrown into the well, spilt water or even surface water directly washing into the well (Cairncross and Feachem, 1993). Figure 5.4 typically depicts conditions of HDW in many rural communities. The well is unprotected from external contamination, it is close to the ground surface and could be susceptible to flooding.

Figure 5.4 Typical conditions of HDW in the study area

High water demand: HDW could be susceptible to high demand can lead to localised drawdown in low permeability soils, resulting in a reduction in yield at the source.

5.4 Groundwater lifting device in Nigeria

Koji (2011) argues technical sustainability of water facility must be reliable, because where a lifting device is non-functioning, it which makes water inaccessible even when it is there Table 5.4 contains common water lifting devices crucial to the sustainability of water service delivery in Nigeria. Usually, water facilities cease to function when the water lifting device develops technical problems ranging from minor to major repairs.

. **Table 5.4 Common water lifting technology**
(Source: Akvopedia, 2016)

Groundwater lifting devices	**Examples**
Bucket and Basket lift	• Rope and bucket, • Swing basket, • Bucket hoist, • Windlasses, • Bucket pump and counterpoise lift
Households or community pumps	• India mark 2 and 3, • Afridev pump, • Rope pump, • PVC pumps etc
Motorised or mechanised pumps	• Solar powered pumps, • Fuel powered pumps, • Horse and wind powered pumps

In Chapters 2 and 3, it was established that technical concerns and the lack of coordinated sustainable financial mechanisms for the operation and maintenance of water facilities are largely responsible for most breakdowns. Where technically sound and financially viable options exist, the current level of about 40% failure experienced in sub-Saharan Africa may considerably reduce (RWSN, 2009, 2010). Consequently, to guarantee continuous water services delivery, technical choices of groundwater lifting devices must be efficient and financially effective for operation and maintenance.

Bhandari and Grant (2007) argue that inappropriate choice of technology and/or poor system design can threaten the sustainability of water services. Lockwood and Smits (2011) pointed out that the proliferation of many different types of technologies makes it harder to ensure that spare parts and expertise are available for operation, maintenance, repairs or standardisation of water technologies. According to Cairncross and Feachem (1993), water technology must be appropriate in terms of cost in order that it can be affordable, perform optimally and be simple to operate and maintained.

Therefore, an appropriate technology must involve the application of basic technical principles in water service delivery so that the solution derived is genuinely suitable to the local context. Hutton et al (2004) conclude that a range of lower cost technologies with low start-up costs for individuals, should be available to allow households and communities to choose their level of service and cost.

Amongst the water lifting devices of listed in Table 5.4 the RPT standout as a simple technology that could bridge the technical gap between handpumps and motorised mechanism as well as provide opportunity to minimise external contamination of

well water using local devices such as rope and bucket. The technology can be technically and financially viable for household when considering self-supply HDW. Harvey and Reed (2004) are of the opinion that the rope pump offers a simple technology that can protect water facility from external contamination, noting that high failure rates of water facilities failures are as a result of insufficient attention to operation and maintenance of conventional water lifting pumps. Therefore, section 5.5 is section aims to explore the potential of the rope pump technology in addressing sustainability issues as a water lifting device.

5.5 Exploring rope pump technology (RPT)

According to Skinner (2003), the rope pump technology comprises a pump with a loop of rope, carrying regularly spaced washers which are continually pulled through a plastic pipe. It has the capacity to lift water at 8L/min from 40m depth. The technology is based on locally available materials with several advantages which include being five to ten times cheaper than traditional piston pumps and suitable for lifting water, especially in lower depth wells (Coloru et al, 2012).

Figure 5.5 illustrates the basic component of the pump. It consists of a continuous rope with pistons attached to it passing over a flywheel down into the well and up through a vertical pipe, the bottom of which is submerged in water. When the flywheel is turned, the rope is pulled through the pipe and each piston traps a column of water inside and raises it to an outlet above the ground surface for users.

RPT is operated in over 20 countries in Africa, with Zimbabwe having produced over four thousand (Holtslag and Mgina, 2009). According to Erpf (2005) study high sales record of over 10 years in Latin America, the pump has become very popular, with users able to

operate, maintain and repair it by themselves. The rope pump simplicity, low cost, easy maintenance and suitability for local manufacture are the attributes needed to enable users to achieve sustainable management of their handpumps and wells (Keen, 2001). According to Harvey and Drouin (2006), the pump provides a significant technological opportunity to improve water supply sustainability in Africa. As mentioned in section 5.3.4 water quality from HDW suggest the need to prevent external contamination of wells.

Figure 5.6 and 5.7 shows HDW with mounted rope pump in Dass community. The Figure shows that the HDW is protected from external contamination by raising the well-head above the ground. Also, the well is covered with sealed concrete slab, which provides additional protection.

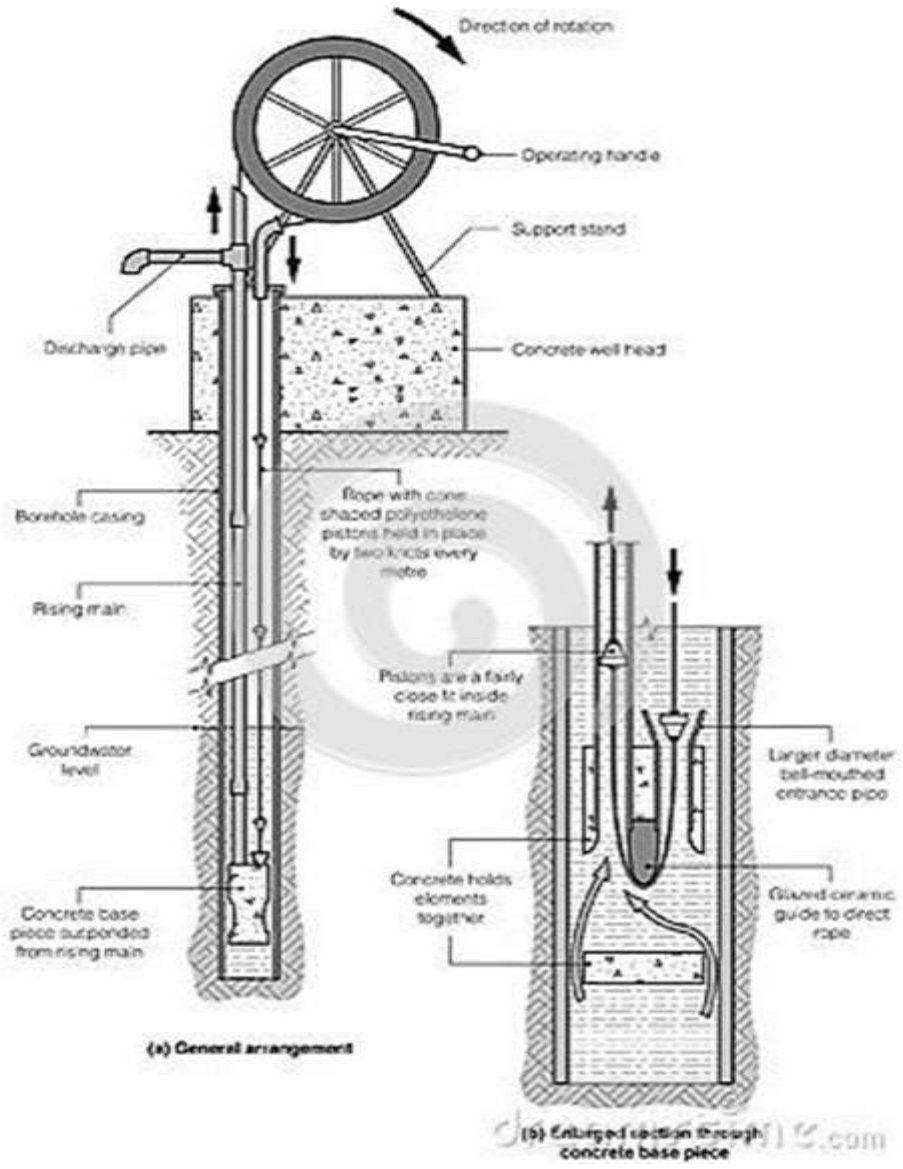


Figure 5.5: Cross section of the rope pump technology (Source: Skinner, 2003)

Figure 5.6: Rope pump in operation

Figure 5.7 Woman operating the RPT

Harvey and Drouin (2006) conducted a comparative performance analysis between the RPT and conventional handpump microbiological water quality indicated that there was no significant difference between pump types with respect to the impact on microbiological

water quality. The RPT also out-performed the conventional handpump on many counts such as rate of discharge contrary to widespread perceptions. The findings of the research included: -.

- The rope-pump demonstrates increased technical performance for all the assessment parameters in comparison to a conventional low-lift handpump and has a near identical impact on microbiological water quality despite contrary negative perceptions.
- The rope-pump is significantly cheaper financially in terms of both capital costs and maintenance costs.
- The financial and technical advantages can be coupled with the fact that the rope pumps are manufactured locally, helping to develop indigenous private sector capacity.
- In terms of financial viability and technical reliability, benefits for the communities, and sustainability, it can be argued that the rope-pump should be actively promoted as a low lift pump for community water supplies

5.5.1 RPT in Nigeria

RPT was introduce to Nigeria in 2010 in WaterAid in collaboration with National Water Resources Institute, (NWRI) Kaduna, following an international technical exchange involving technical personal of some stakeholders from Nigeria in Burkina Faso and Ghana West African. A National Technical Core Group (NTCG) on rope pump development was set up to oversee the development and standardization of the model. The imported models were piloted in 3 State such as Plateau, Bauchi, Kaduna and Federal Capital territory Abuja.

The model has gone through various stages of improvement to adapt it to local demand and durability. Figure 5.8 shows a three-dimensional drawing of improved version of the pump head in Nigeria.

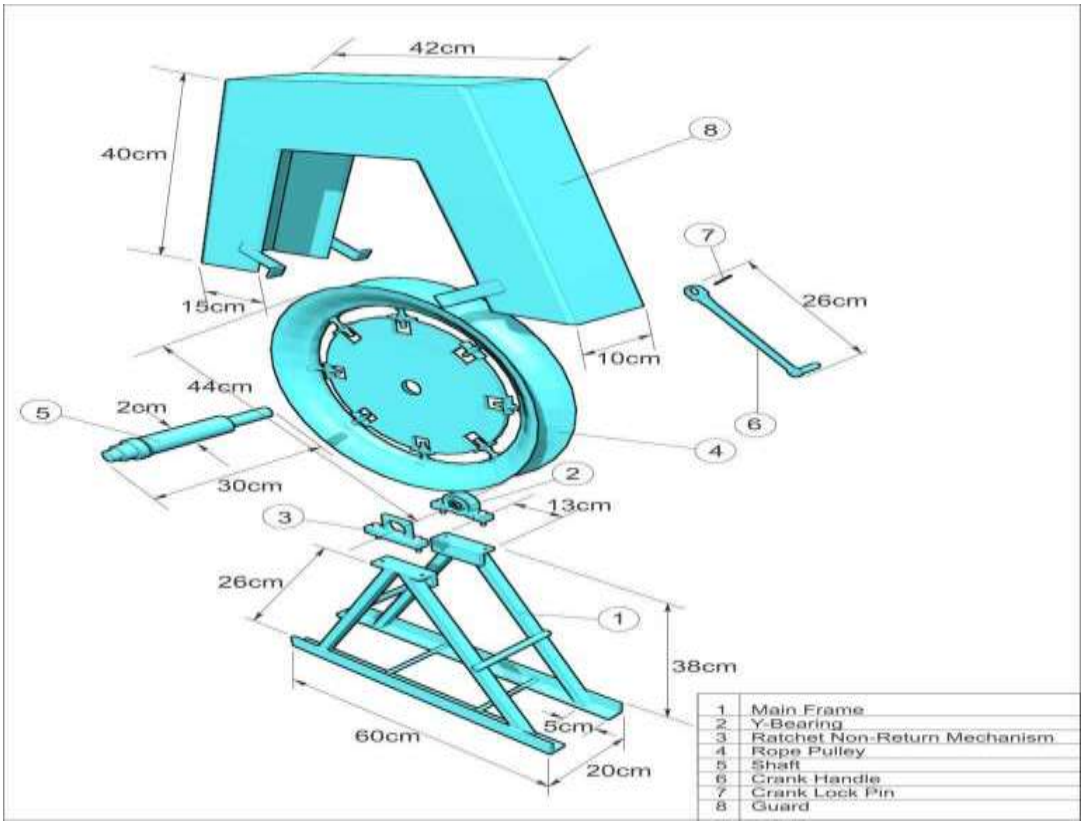


Figure 5.8: Components of Rope-pump technology pump head (Source: Author, 2014)

The above demonstrate that the concept and technology of the rope pump is still developing. Therefore, exploring it potential in conjunction with HDW could provide a manageable rural water facility to many rural dwellers in Nigeria.

5.6 Community Based Water Resource Management (CBWRM) concept

Brikke (2000) among the main characteristics of sustainability discussed in section 3.3 stated sustainable water service is that which does not affect the environment negatively. Hence, while exploring the option of self-supply-HDW and the use of RPT, it is important to take into consideration the potential impact this approach could have on local water resources, if adopted by many individuals and households a community.

The concept of water resources management according to ICE (2011) is the ability of water sources and water resources to continue functioning and yielding water into the long-term future, without detriment to any water users, including the environment. It is a set of relationships designed to improve localised management of water resources, and so enhance resilience to threats such as increasing demand, environmental degradation and climate variability. It is about involving water users in the day to day management of local water resources, (Damiba et al, 2013).

As earlier discussed in previous sections, groundwater has also been proven to be the most reliable resource for meeting rural water demand in sub-Saharan Africa (Macdonald and Davies, 2000). Its role in sustaining livelihoods, environment sustainability, time and resources cannot be over emphasised. It offers security when surface water supplies fail during dry seasons. Groundwater resources in the form of boreholes and handdug well are the most important sources of public and private water sources in urban and rural areas of Nigeria, however, its exploitation is currently minimally or virtually unregulated (Nwankwoala, 2014).

As result, Adelana et al (2010) noted that groundwater contamination in rural areas has recently become the primary subject of groundwater investigations, because of increasing use of potential contaminants. However, Koji (2014) points out that good design and construction of water supplies is essential to prevent water contamination because the poor construction of the water points has the potential to lead to the risk of a direct intrusion of a contaminant into the groundwater.

5.6.1 The Dublin principles on water resource management

Dublin principles 1992, provided the basis of global water resource management. It acknowledge that scarcity and misuse of fresh water pose a serious and growing threat to sustainable development and protection of the environment. Human health and welfare, food security, industrial development and the ecosystems on which they depend, are all at risk unless water and land resources are managed more effectively in the present decade and beyond than they have been in the past. The following are the guiding principle for water resource management from the Dublin Statement on Water and Sustainable Development, 1992.

- Principle No.1: Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.

- Principle No. 2: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

- Principle No. 3: Women play a central part in the provision, management and safeguarding of water.
- Principle No. 4: Water has an economic value in all its competing uses and should be recognised as an economic good.

According to GWP (2012) past inability to effectively manage water resources is associated with failure to recognise the economic value of water. Although the Dublin principle has been advocated at the global, regional and national level, practical application and implementation have been a challenge. The ICE (2011) developed an institutional landscape for water resource management concept that can be operationalised at the community level (See Figure 5.9)

The Figure shows institutional landscape, aimed at water sector leadership and regulation, service delivery and provision. It seeks to increase decentralization of water resource management from national, regional to the local communities taking advantage of local knowledge at the community level towards sustainable water resource management. The diagram points to the need to engage at the local and communities level as well as an institutional strategy for water resources management. However, the methodology and guidelines on reaching to households at the grassroots in the communities effectively were not clearly articulated.

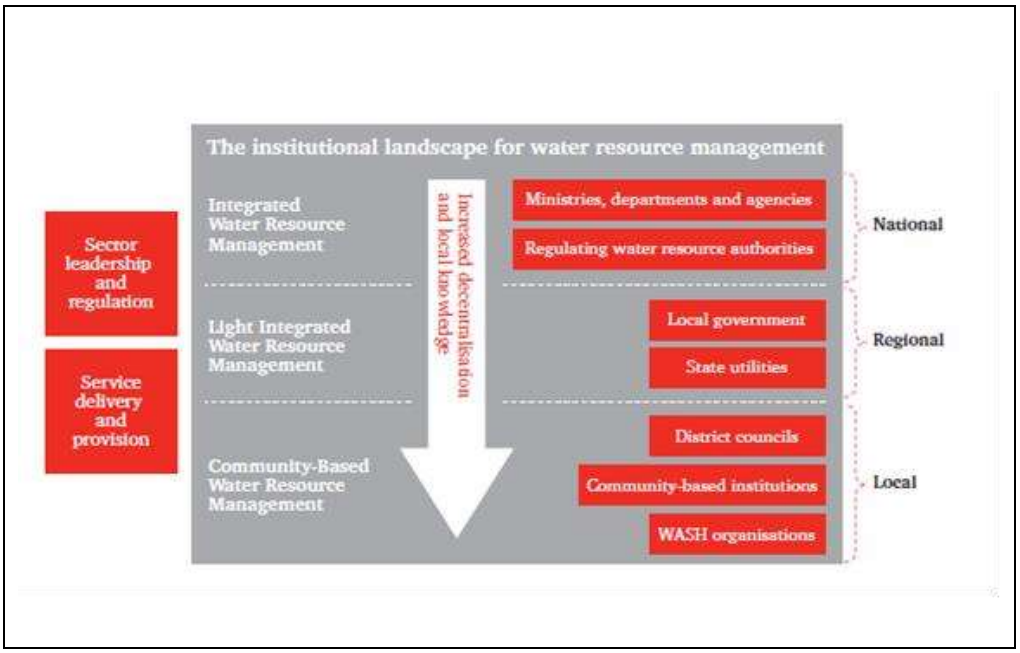


Figure 5.9: Institutional landscape for water resource management. (Source: ICE, 2011)

The idea of mainstreaming CBWRM into sustainable water service delivery requires an understanding of local water context as well as the potential of adapting the Dublin principles to local communities. According to Oloke and Olugboye (2015).

- Communities can monitor groundwater resources in order to observe changes water level and their environment and also establish appropriate management techniques and subsequently use local data to inform decisions on their sources in both quantity and quality.

- Communities can respond to changes in water availability through collective decisions bound by clear operating principles for water usage. During the dry season, rationing can be introduced. This can help to achieve better coordination and prioritisation of water use. The agreement can be reached on formal allocations for different water uses and different users. In many cases, communities prioritise drinking water use over other needs and may place restriction on certain water uses such as brick-making, gardening, animal husbandry or clothes washing.

- Communities introduce sanctions when necessary on erring community members found to mismanage water resources or carrying out environmentally damaging activities.

- Communities can inform the design of water facilities to meet multiple water needs, build the capacity of communities to identify an early warning system as well as strengthen the communities to call for assistance when access to water is threatened beyond their capacity.

The above suggest that there are prospects not only to enhance sustainable water supply access to a rural community, but also safeguard ground water resources from within the community at household levels. This study will undertake to elicit ground water user perspectives on the Dublin principles of water resources management to inform the development of the proposed guidance framework.

5.7 Chapter Summary

The chapter explored alternative options for rural water sustainability based on technical and financial viability. In addition, the chapter highlighted environmental sustainability, which hitherto have been relegated to the background in rural water supply service provision. For long, focus has remained on increasing service coverage rather than attaining an overall system sustainability.

The chapter explored the concept of self-supply as individual effort towards water facilities provision to meet their need is proposed. This idea supports users taking responsibility for construction, operation and maintenance of their water facilities without waiting or relying on external support to meet their water need. It was also clear that hand-dug well (HDW) has huge potential in realising self-supply. However, HDW have peculiar challenges with their construction, operation and maintenance, water quality, and variation in seasonality. Hence, rope pump technology was identified as potential mechanism that could address some of these challenges in relation to financial, technical and environment concerns of managing water facility based on findings in literature.

Although, the concept of self-supply, HDW and the use of rope pump technology hold a potential for sustainable water service delivery in Nigeria, there is a need to adequately consider issues around ground water resources due to increased population, climate change variability and other human activities. The chapter discussed the need to engage in a community based water resource management to as ensure that meeting present water need does not jeopardise the prospect for future generation to have the need meet. Therefore, the research will seek perspectives of users on the enabling environment for self-supply, the viability of RPT and Dublin principles on water resource management discussed in the chapter. Hence, the concepts reviewed in literature will inform methodology for field data collection discussed in chapter 6.

Chapter 6

6.0 Research Methodology

6.1 Introduction

This chapter highlights the methodological approach adopted during this research, it will describe the background, theories, processes and events that guided the research actions. The chapter will also explain the processes, from which the research data are generated. This includes an overall research design, data gathering processes and fieldwork. Special attention was given to the sources of data, the rationale underpinning data selection and collection method. Overall, it explained how the process evolved based on consideration of various research approaches.

6.2 Background to Study Area

Dass Local Government Area (LGA) is one of the 20 local government of the Bauchi state Nigeria. It is in the north-eastern geopolitical region of Nigeria. It has a total land area covering of 535 km² and about 58 km from the state capital. The total population was 89,943 according to 2006 census figures. Figure 6.3 the geographical map of the area. Figure 6.1 shows the map of Africa and location of Nigeria. It further projects the map of Nigeria showing Bauchi State. Further projected to the right is the map Bauchi state showing Dass LGA. The picture at the Bottom shows the map of Dass with digital location of water facilities.

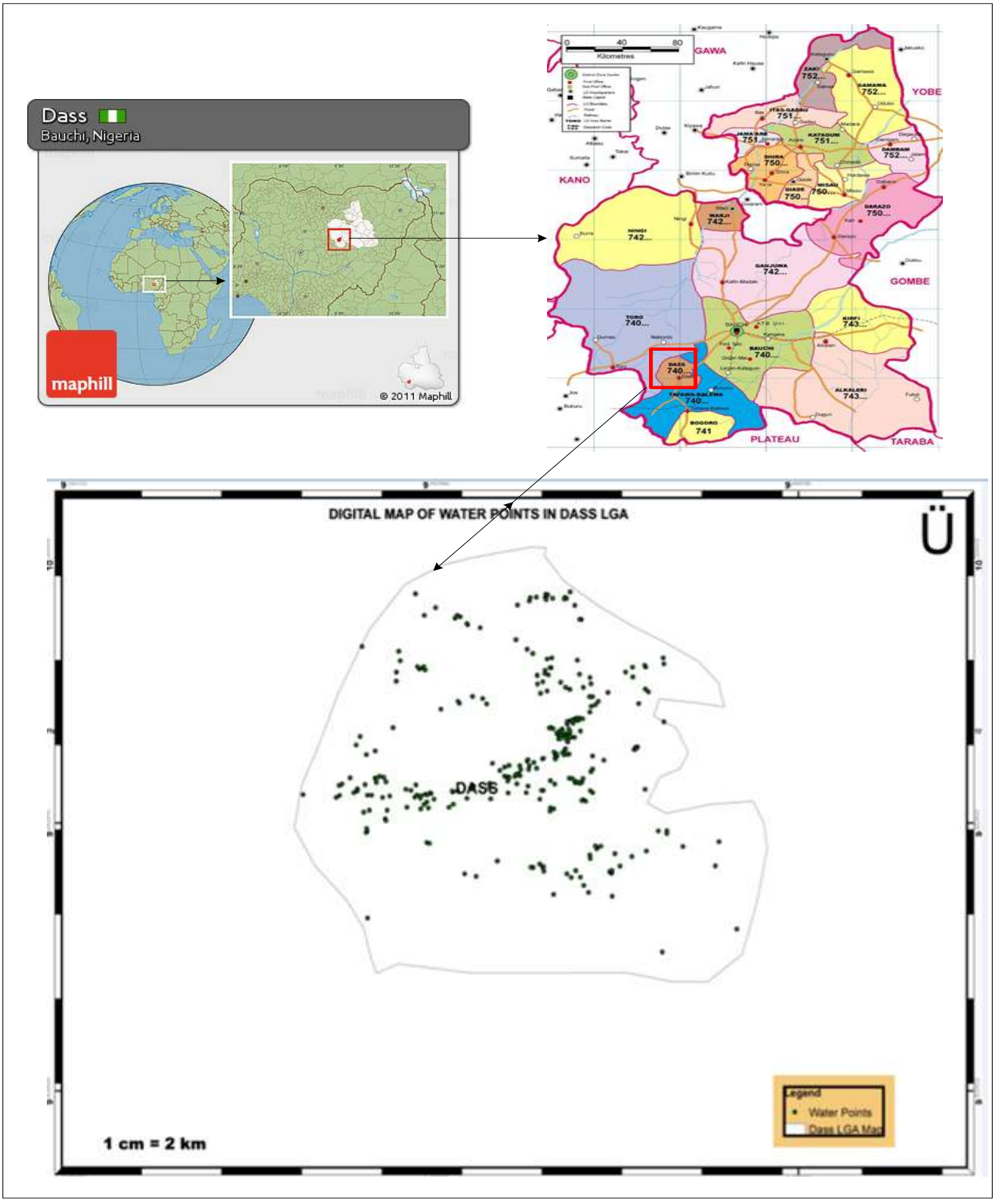


Figure 6.1: Study area and water facilities location

6.2.1 Climate

The area is characterised by two distinct climatic seasons; dry and rainy seasons. It is located within the Guinea savannah type of climate with 6 -7 months of rainfall, usually starting from April and October and dry season from November to March every year (see Figure 6.2). The temperature in the area is relatively high with mean annual temperature of 30°C. The climate is tropical, temperature ranges between 12^{o} C and 30^{o} C and relative humidity between 10-43% (Anosike et al, 2003).

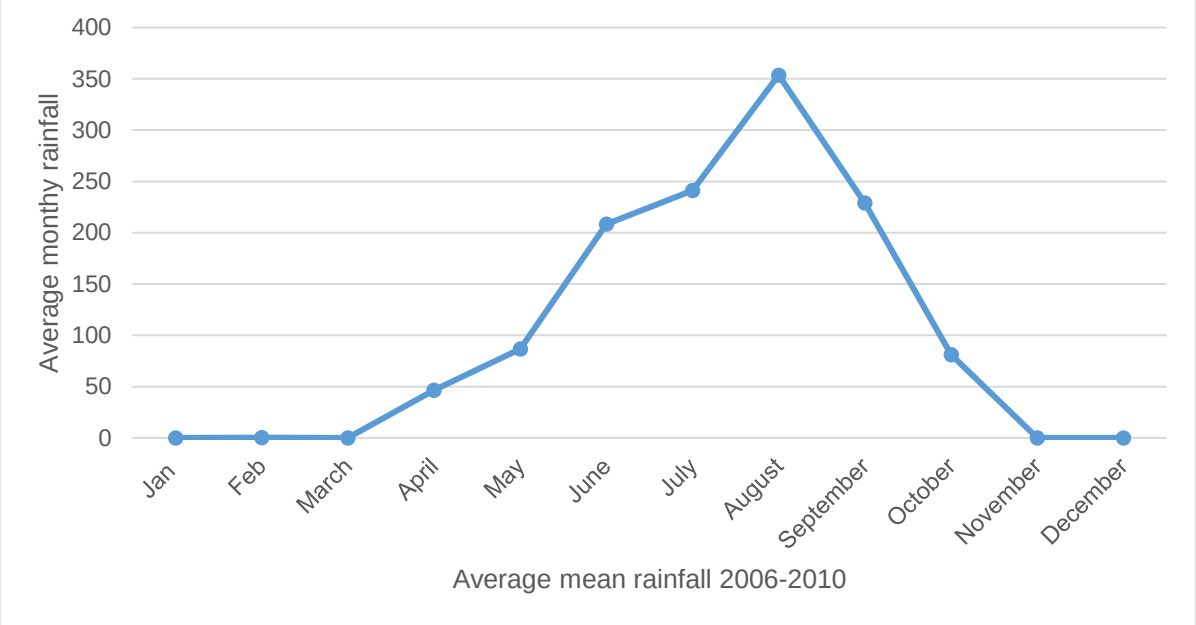


Figure 6.2: Average monthly rainfail in Bauchi State
Source: (Nyanganji et al, 2011)

The area experience cold dry wind of continental origin that forms part of the dusty Harmattan wind that is experienced from December to February and in some instances, up to March as it does in most parts of northern Nigeria (Nyanganji et al, 2011)

6.2.2 Soil and vegetation

The area has a typical Guinea Savannah vegetation, having grasses up to 2m tall, and trees and shrubs are usually green and fresh during the rainy season. During the dry season the environment gets patchy and dry with trees and shrubs shedding leaves to conserve water, developed resistance against the dry weather condition and bush burning (Iloeje, 2009). Soils in Dass are mainly clay loams that graduate into the sandy loam and gravelly soil towards the hillslope. Alluvial soils are found around the fadama and on the flood plains (Nyanganji et al, 2011)

6.2.3 Geology

Dass is located on the basement complex rocks of the North Central Highland. It is characterised by plutonic rocks that solidified at some depth within the earth's crust. Solidification of the rock was slow, forming large crystals of rock of coarse grain size. The granite, gabbros, migmatite, gneisses and diorite that are seen on the surface in the study area are now exposed to the surface by denudation activities and erosion. Many private wells in the area obtain water mainly shallow wells ranging between (2.6 – 5.0) metres deep. Similarly, disposal of human and related household refuse into latrines and waste disposal pits are also done in shallow pit. Unfortunately, considerable population of the people in the area depend on this shallow and mineral deficient source of groundwater for general domestic use and consumption (Nyanganji et al, 2011).

6.2.4 Reasons for the selection of location for the study area

The area was selected for this study based on the following reasons:

- It has significant access to groundwater resources that support the use of HDW
- It has a sizeable number of households using HDW wells in the area
- It has benefited from rural water supply, sanitation and hygiene interventions from government at all levels as well as other externally supported agencies
- It is a multicultural community that is representative of larger Nigerian society
- There is relative ease of access to the communities, water facilities, man power and logistical support. The airport is about 58km away and connects domestic flight regularly from the nation's capital Abuja.
- The researcher has a good working knowledge of the area, the culture, and has the ability to communicate effectively in the local language.

6.3 Review of research methods

Naoum (2003) states that the selection of the type of research strategy is determined by the purpose of the study and the type and availability of information that is required'. Rudestam and Newton (2001) suggest that the method used should be 'sufficiently rigorous and appropriate to the research question' so as to 'successfully evaluate a completed study irrespective of the study being conceptually and/or theoretically grounded'. Hence the adoption of a research strategy will affect the final form of the dissertation.
Amaratunga et al.,(2002) points out that there is no consensus in literature on how a research methodology should be defined.However, Yin (1994) opined that a research design should connects the generated empirical data to the initial research objectives of the study in a logical sequence and ultimately to its conclusions.

6.3.1 Quantitative research

Creswell (2003) defined quantitative research as an inquiry or 'investigation into a common or "human problem", by carrying out an assessment of hypothesis or a theory made up of variables, that are evaluated with numbers and analysed with statistical methods in order to determine the accuracy of the hypothesis or theory'. Quantitative research involves the use of research methods such as questionnaires, interviews, observation and documents which generate quantitative data (Denscombe, 2007). These definitions therefore agree with the view of Naoum (2003), Creswell (2003), and Rudestam and Newton (2001) as they imply that the quantitative research approach is suitable for finding and collecting facts about a study.

The quantitative research approach, therefore, applies rational methods that involve generation of numerical measurement of observation and verification of the theories and laws that govern the single objective reality out there in the world (Clarke and Dawson 1999). Quantitative research approach is objective in nature. This objectivity is an underlying concept that was a focus throughout the research process as the aim of the study was considered to be objective in nature as well. Quantitative data are not abstract but ' hard and reliable measurements of tangible countable, sensate features of the world' (Bouma and Atkinson, 1995). The quantitative research approach in the context of social science is normally used to investigate a social or human problem based on testing theoretical assumptions upon collection and analysis of empirical data to determine whether the predictive generalisation of a theory is valid (Creswell, 2009). Quantitative research approach is characterised by the following features:

1. The researcher is kept distant and independent from the sample to achieve an objective and unbiased assessment of the situation.
2. It uses a deductive form of logical reasoning, such that concepts, variables and hypothesis are chosen and maintained from the beginning to the end of the study.
3. It often uses statistical packages to carry out descriptive and inferential numerical analysis of the data, so as to test the reliability and validity of the result

6.3.1.1 Benefits of quantitative research

Denscombe (2007) observed that some advantages of quantitative analysis were that they provide answers to closed-ended questions obtained from questionnaire helped with content analysis of transcripts obtained from interviews were seen to be are suitable for measurements of experiments, or observation schedule used with events and they also provided official statistics obtained from documents. He further, noted that the method brings about confidence as the 'statistical tests of significance' provides added credibility to the researcher's data interpretation and findings and that process gives the foundation for the authentic measurement, description and analysis of quantities which can be checked by anyone. The method in addition to the foregoing, also allows for a large amount of data to be analysed relatively faster and the mode of presentation of quantitative data is considerably more effective and succinct using tables and charts.

6.3.1.2 Quantitative data collection

There are different ways of collecting data in the quantitative research approach. These include observation, documentary evidence and questionnaires (Abdulai, 2007). According to Denscombe (2007), questionnaires are mostly used in conducting surveys to find out

facts, opinions and views of the target group or individuals, which mostly contain close-ended questions in which respondents are offered response choices like Yes or No, Agree or Disagree, ranking in order of preference or importance and so on (Denscombe, 2010). In some cases, questionnaires contain open questions that seek to encourage the respondent to provide free responses without any choice (Neuman, 2006). Questionnaires may be administered in different ways; face-to-face interviews, postal, telephone, fax, internet or web-based surveys and so on (De Vaus, 2002).

6.3.2 Qualitative research

Qualitative research gives a detailed description of events, people, interactions and observed behaviours (Patton, 1992) and general opinion. It gives a description and explanation of both perspectives and behaviour of the people studied (Brannen, 1992). Bell (2005) argues that researchers adopting a qualitative approach are more interested in understanding an individual's outlook of the world. Therefore, a qualitative researcher looks for insights instead of statistical perceptions of the world. In a qualitative research, different forms of data can be collected in different ways; observation, interviews and documentary evidences (Abdulai,2007; De Vaus, 2002). The most common method used to collect qualitative data particularly in exploring complex situations is an interview (Denscombe, 2010).

The approach is perceived as an appropriate way of collecting in-depth facts and opinions relating to the circumstances studied. The interviewer basically asks the respondents certain designed questions directly related to the research to collect answers vital to the research aims and objectives (Bailey,2007). In qualitative research, information gathered can be classified under two categories: exploratory and attitudinal research (Naoum, 2013).

Exploratory research: This research is used when the researcher has a limited amount of knowledge about the research topic. The purpose is closely linked with the need for a clear and precise statement of the recognised problem.

Attitudinal research: This research is used to subjectively evaluate the opinion of a person or a group of people on certain attributes, variables, factor or questions. The main examples of qualitative data collection are individual interview, focus groups, direct observation and case studies (Hancock, 1998).

Rubin and Rubin, (1995) argues that a qualitative research must be flexible, iterative and continuous. These principles aligned with explorative nature of this research, were highlighted by Webster, (2006) as follows:

Flexibility: This allows the researcher to be responsive to the new avenues of inquiry the investigation opens. It allows the researcher to shift direction and follow leads (Neuman, 1997).

Iterative design. Qualitative research is non-linear is more of a spiral, moving slowly upward but not directly. With each cycle or repetition, a researcher collects new data and gains new insights (Neuman, 1997).

Continuous design: Flexibility and continuous design work closely together. Ideas emerge in the first stages of data collection of such research that lead to the use of other techniques.

Thus, according to Bashir (2013), qualitative research approach has inductive orientation and involves exploring to understand a social or human problem in which data

is mostly collected from participants in their natural setting using emerging flexible questions and procedures.

6.3.3 Difference between quantitative and qualitative research

The distinction between 'quantitative' and 'qualitative' research relates to the treatment of data rather than the research methods and both research approaches are not mutually exclusive in practice. This is because most social researchers seldom depend on one approach while excluding the other; but rather the assumptions made from the two approaches were usually shared, usually overlap and do not often rest on opposing sides. (Denscombe, 2007). Table 6.1 highlight differences between qualitative and quantitative Research Approaches.

Table 6.1 Difference between Qualitative and Quantitative Research Approaches (Source: Denscombe (2007)

S/N	Quantitative Research	Qualitative Research
I.	Associated with numbers as the basis of analysis	Associated with words or images as the basis of analysis
II.	Interpreted with statistical analysis	Uses descriptive analysis.
III	Lends itself to large-scale studies	Suited to small-scale studies
IV.	Looks at a specific aspect or focus in relation to other specific aspects	Embraces a holistic perspective that views things in context
V.	Allows for the researcher to be objective and detached such that data are presented independently without undue influence or bias from the researcher	Involves the researcher's 'beliefs, values identity and social background' in the data collection, interpretation and presentation.
VI.	Based on a programmed 'research design'	Based on an emerging 'research design' (an on-going process in which evolving theories are tested such as 'grounded theory' Glaser and Strauss 1967 in Denscombe 2007)

6.3.5 Mixed method research

The field of mixed methods has only been widely accepted for the last decade, though researchers have long been using multiple methods, just not calling them "mixed." The methods have become prominent within the social technical research community through researchers such as Tashakkori and Teddlie (2003), Gorard and Taylor (2004), Johnson and Onwuegbuzie (2004). Dare (2011) claimed that mixed methods approach enable researchers to avoid bias in the research approach and methods used as well as in the validation of results. The method presents an opportunity for the combination of both qualitative and quantitative research methodology which has proven to be more powerful than a single approach (Moffatt et al., 2006).

6.3.5.1 Advantage and disadvantage of mixed-method research

The mixed method research has several advantages, amongst which are that it provides a more in-depth account of subject study, establishes clear link to different methods, and supports the good use of triangulation to validate. Some disadvantages of this research are that greater time is required for data collection, a cross cutting additional skill may be required, and results may differ significantly from one approach to other approach used. The advantages and disadvantages are summarised in Table 6.2.

Table 6.2 Advantage and disadvantage of mixed-method approach (Source: Denscombe, 2007)

Advantages	**Disadvantages**
(a) Provides a more comprehensive account of the subject being researched;	(a) The likelihood of the time and cost of the research project to increase, due to the combination of different approaches;
(b) Clearer links between different methods and the different kinds of data;	(b) The need for the researcher to develop and use skills relevant to both qualitative and quantitative research approaches
(c) Good use of triangulation; and practical, problem – driven approach to research'	(c) Disagreement between the results obtained from the different approaches

Mixed method approach is distinctively characterised by three major features as summarised by Denscombe (2007) as follows.

- It combines the use of the qualitative and quantitative approaches within one single research project, as it in many research project, where researchers brought together certain tools and elements of qualitative and quantitative methods and data analysis in order to arrive at the research findings presented.

- There is a direct focus on the link between approaches; the mixed methods approach is said to lay more emphasis on explaining why the varied approaches used were arguably more beneficial. It also emphasis on how these alternative approaches can be unified with greater attention being given to the mixed methods research design.

- There is emphasis on providing practical solutions to research problems; Denscombe (2007) noted that this was a pragmatist approach and that the mixed methods approach was problem-driven.

6.4 Adoption of Research methodology

In many research efforts, the choice of research approach is usually a challenge, often due to concerns over which should be the most appropriate approach. However, it has been established that no one research approach is better than the other because all the approaches have their own merits and demerits (Bowling, 2002). As such, it is recommended that the adoption of a research approach, must be supported by clear basis for its adoption (Hammond, 2006). To this end, therefore, several reasons are usually articulated in literature for selection of research approaches such as the research problem, the research audience, and the availability of resources and the personal experience of the researcher (Abdulai, 2007).

According to Yin (1994) there is neither a fast rule nor best research methods, the use of each research method depends on the form of research question, the research objectives and contextual situation, type of data needed for the research determines the most suitable research method. Research methodology have been reviewed 6.3.0 - 6.3.5.1. Table 6.3 presents a research method strategic selection process mapped against various possible scenario (Yin, 1994).

Table 6.3 Research design strategy
(Source: Adapted from Yin, 1994)

Strategy	Form of research question	Required control over behaviour and event	Focus on contemporary event
Action research	who, what, why, how many, how much	Yes/No	Yes
Case study	How, why	No	Yes
Survey	who, what, why, how many, how much	No	Yes
Archival analysis	who, what, why, how many, how much	No	Yes/No
Modelling	who, what, why, how much	No	Yes/No
History	How, why	No	No
Experiment	How, why	Yes	Yes

From the foregoing, a research on exploring opportunities for sustainable rural water service delivery is a cross cutting subject embedded in both social and technical perspectives. Hence, a combination of exploratory and descriptive approach using qualitative, quantitative can be considered as mixed method approach. The method allows a researcher to both generalise findings to a population and develop a detailed view of the meaning of a phenomenon or a given concept in this case sustainable water service delivery concept (Creswell, 2003). Also, being an exploratory research, the method enables the researcher to develop an instrument to be subsequently administered to a sample population (Creswell, 2009).

This study adopted several data collection techniques, because the types of data being sought are both qualitative and quantitative in nature. The approaches considered were thus

hinged on these considerations. Lots of time, effort and care was put into the process of data collection in-order to acquire as much relevant data as was possible. The main emphasis, as stated, is on 'what', 'how', 'how many' and 'why' type questions, which lend themselves to the selection of mixed method.

6.5 Research design and approach

According to Amaratunga et al. (2002) research design can be considered as logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation. He also opined that research design serves as an architectural blueprint that links data collection and analysis to the research questions. thereforeResearch design is essentially a logical sequence of steps linking the initial research questions to the data collected and ultimately to a series of conclusions arising from the study (Yin, 1994).

The purpose of a research design is thus more than establishing a work plan for the study; it is to ensure that the logic of the study's approach is maintained, thereby avoiding situations in which the evidence fails to address the initial research question(s) posed. (Yin, 1984) however, argues that research designs should comprise five components. These are:

1. A study's questions;
2. Its propositions, if any;
3. Its units of analysis;
4. The logic linking the data to the propositions; and
5. The criteria for interpreting the findings

The research adopted pragmatic mixed method approach. It was considered most suitable for this study since the subject area cuts through social and technical line of inquiry. The approach provided the opportunity to use methods, techniques and procedures typically associated with quantitative or qualitative research. This was done having recognise each method individually has its limitations as earlier discussed in this chapter. The mixed methods research takes advantage of using multiple ways to explore a research problem. This is with a view to overcome the limitations of a single design. Hence, the design is characterized by an initial collection and analysis of quantitative data followed by a collection and analysis of qualitative data. The purpose is to use qualitative results to assist in explaining and interpreting the findings of a quantitative study (Creswell, 2013).

According to Creswell (2009) some studies use qualitative and quantitative methods sequentially, simultaneously such first one approach is used and then the next, with the second part of the study perhaps expanding on the results of the first or in a multilevel design approach. In this research, quantitative study involving household questionnaire surveys, inventory surveys, sanitary risk assessment and water quality test well as qualitative methods such key informant interviews, informal discussion, direct observation on the field which serve to obtain information which was use to contribute towards the development of user perception surveys using Likert scale, the results of which was analysed statistically.

6.6. Data collection techniques

The data collection approaches relating to quantitative and qualitative methods in the research is described in this section. To achieve the objective of the research data were collected by the researcher and supported by research assistants in the administration of surveys, questionnaires and field observation. Figure 6.3 shows a field measurement of well depth using tape rule. and Figure 6.4 highlights the various data collection method deployed in the study.

Figure 6.3 Field measurement of Hand-dug well depth using tape rule

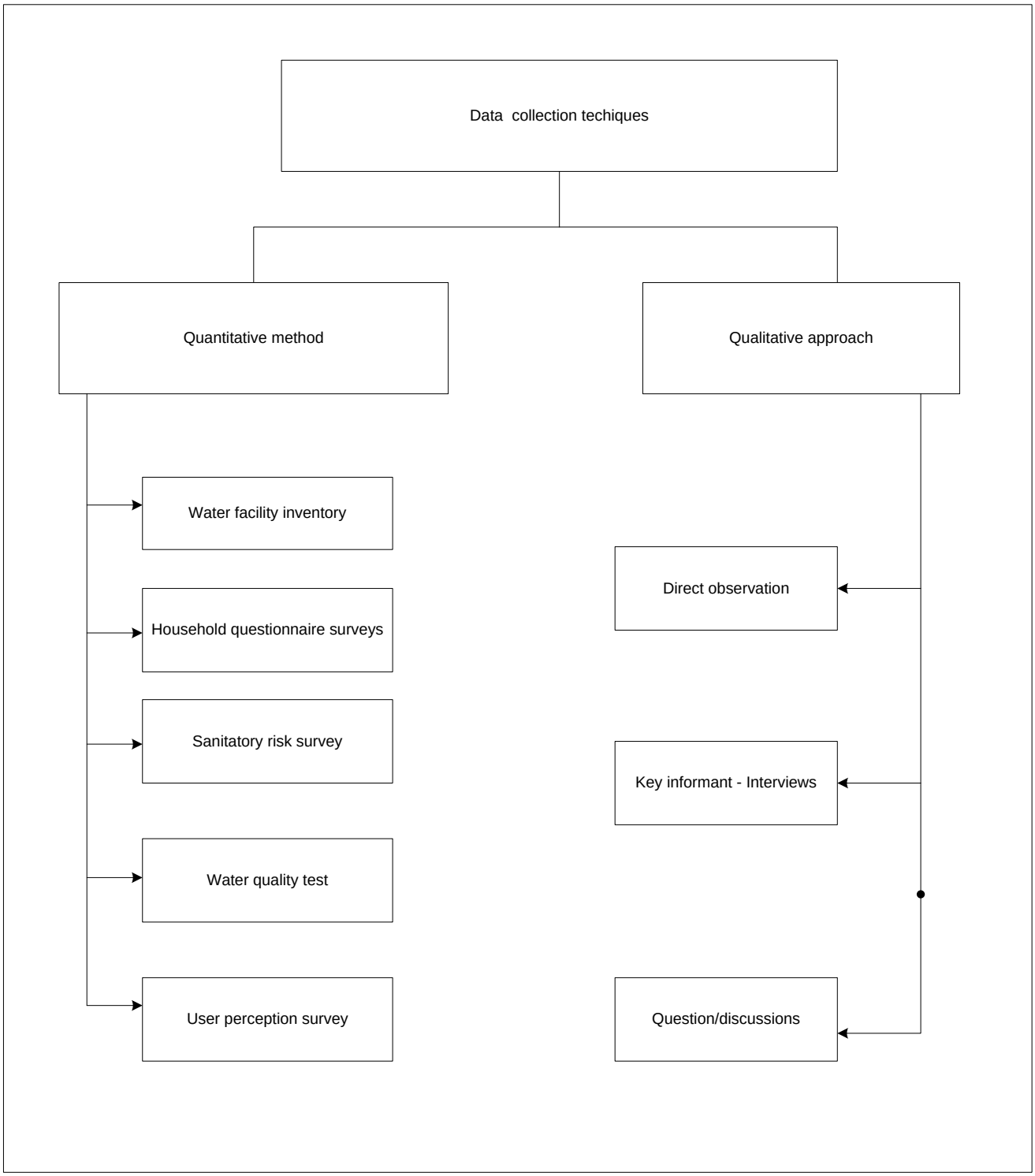


Figure 6.4: Research data collection techniques
(Source: Adapted from Oluwasanya, 2009)

6.6.1 Sample size calculator

Figures 6.5 shows sample size calculator provided by the Survey System. It is an online software has reputation for survey creation, analysis and administration methods, making it one the best survey software available to researchers. The tool can be used to precisely determine sample size of population. This ensure the result reflects the target population. For example, to determine sample size for population of 382 people, using a confidence level of 95% and confidence interval of 10% will require 77 samples. The application will be used for subsequent sample size determination where applicable.

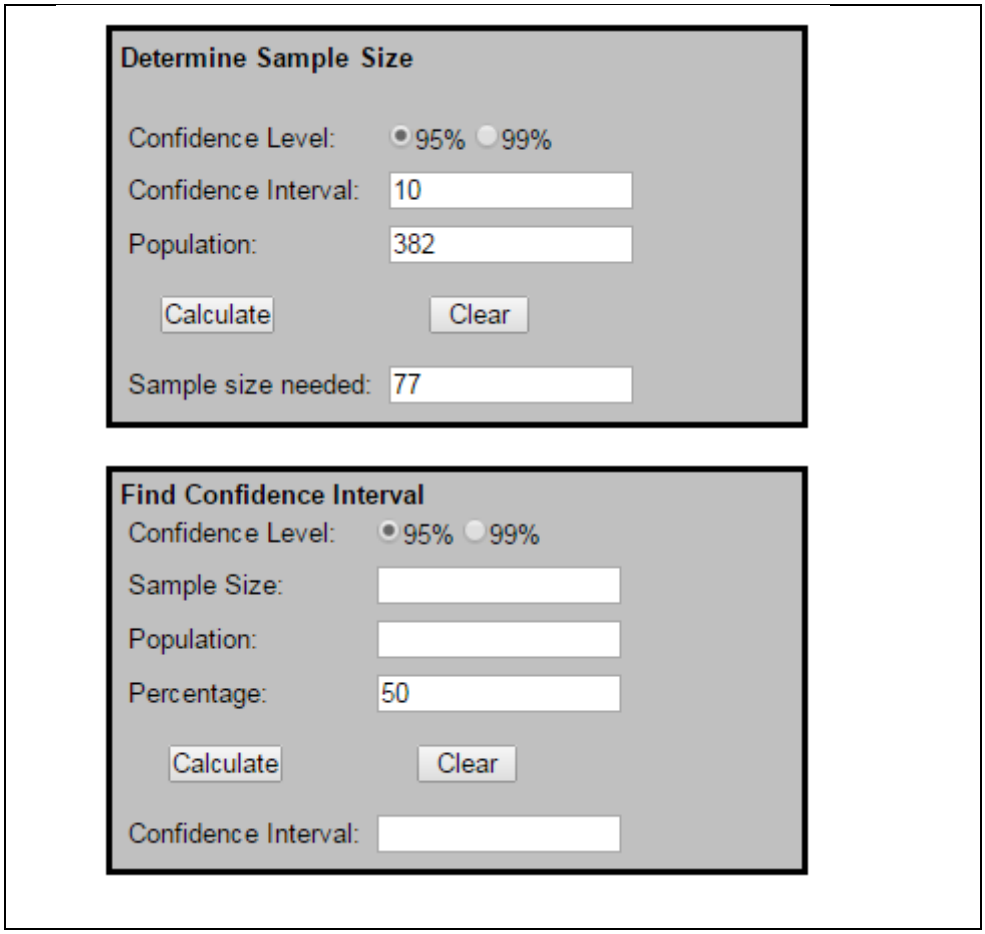


Figure 6.5: Sample size calculator
(Source: Survey System, 2012)

6.6.2 Sampling techniques (Adapted from Bashir 2013)

The following 3 types of sampling techniques were used at various stage of data collection in the study area.

Random sampling: this were each member has an equal opportunity of being included in the sample (Denscombe 2007). For instance, a researcher may put the names of all the members of a population in a hat, waddles the hat and thoughtlessly picks a portion of the names to form members of the sample. A major disadvantage is that the members may not be a true representative of the whole population (De Vaus 2002). This method was adopted for the selection of inventory of water facility functionality.

Purposive sampling: This is one of the most recommended sampling techniques for qualitative studies based on interviews (Bryman 2008). It is strategic technique where samples are selected based on their relevance to the research question (Denscombe 2010). Boreholes water samples were purposefully selected close to HDW to ascertain the level of the microbial contamination in HDW and boreholes located in close proximity.

Convenience sampling: In this form of sampling, the researcher does not have a special screening criterion. Data is collected from whoever is available or made available by an organisation and can participate in the study (Bryman 2008). 50 participants of the perception surveys were selected based on availability, voluntary participation and convenience.

6.7 Research fieldwork

The field visit was undertaken over 16months between May 2013 and September 2014. At the early stage of the fieldwork, time was devoted to stakeholders' engagement, community sensitisation and mobilisation. The level of community participation in developmental activity is dependent on the degree to which the stakeholder has been mobilised (Andrade Neto, 1999), hence, stakeholders identified were sensitised on the aim and objectives of the research. The field visits were designed to give a broad perspective on seasonal variations in water sources and water facilities use in the area. Due to the enormous task of collecting research data at various stages of the field work, research assistants were engaged. The assistants were trained and knowledgeable individuals in rural water supply and management system.

The first field study was aimed at generating data on functionality of water facilities in the study area by taking inventory of water sources and directly observing user attitude and practices on water facilities. Subsequently, sanitary risk and water quality assessment were conducted. Results of these initial findings informed subsequent interviews and user perception surveys and informal discussions on the concept of self-supply hand-dug wells, , rope pump technology and community based water resource management.

6.7.1 Water facilities inventory survey

unpublished documentary sources from state agency data base of improved water in the study area shows that there about 380 water facilities comprising of about 370 handpumps and 10 motorised boreholes. Using the sample size calculator discussed above, 78 water facilities inventory survey was conducted using data sheet (See Appendices: B).

The facilities were selected sampled to reflect the study area water facility coverage. The purpose of the inventory survey was to ascertain facilities functionality status. This was done with a view to compare the level of breakdown of improved water facilities such as handpump and motorised boreholes in the study area with non-functionality rate of about 40-60 % in sub-Saharan Africa (RWSN,2009).

6.7.2 Household questionnaire survey

The household survey used was a semi structured survey questionnaire, it was designed to provide data on the household respondent age, sex, level of education, occupation, and issues in relation to basic water supply sources and management in the study area (See Appendices: D). The household questionnaire was adapted from standard household survey questionnaire widely used in the sector as recommended by WHO and UNICEF (2006) It was administered face-to-face. Although the approach was strenuous and time consuming. Its improves the accuracy of the data, as well as allows more representative data collection of the population.

For households visited, the researcher or assistant introduced themselves, stated the purpose of the survey and asked for permission and time. It was recommended that the data collectors ask the questions to a resident member of the household to make sure the respondent is in the best position to answer the survey questions. Although the household survey was targeted at one member of the household, in many cases more than one person was present at a time of conversation, this was considered an advantage as other people present tend to validate or argue for the most appropriate response.

The sample size was determine using Survey System sample size calculator provided by Creative Research System (2012). By using the study area population of 89,943 (National Population Commission 2006), a confidence level of ($p < 0.10$), a sample size of 96 was calculated for household respondents. Detailed outcome and analysis of the household survey is presented in chapter 7.

6.7.3 Borehole and HDW selection

The study is aimed at exploring sustainable water service delivery, the focus was on how HDW as water source can be improved to deliver efficiently in relation to technical, financial and environmental sustainability. Boreholes and HDW are widely spread in the study area. 50 HDWs were selected at random and 10 boreholes within 10m of HDW were purposefully selected. The boreholes selection was based on the assumption that proximity to HDW may likely expose them to a similar level of sanitary risk conditions. This is done with a view to compare the amount of biological contamination that may be present in the water samples.

6.7.4 Sanitary risk inspection surveys

The study adopted the WHO (1997) sanitary risk inspection survey tool as part of the comprehensive and complementary risk-based assessment of drinking water quality. It identifies potential sources of contamination of groundwater abstraction water points, such as HDW (Mushi et al, 2011). According to Luby et al (2008), the survey can support the operation and maintenance of water points by providing clear guidance for remedial action to protect and improve water supply. Sanitary survey forms are used based on the WHO Guidelines for Drinking-Water Quality (Howard, 2002; WHO, Davison et al., 2005). For

each water facility observations were scored and recorded in unified formats for easy assessments.

The sanitary inspection format (See Appendix C) consists of a set of questions which have "yes" or "no" answers. The questions are structured such that "yes" answers indicate that there is a reasonable risk of contamination and "no" answers indicate that the particular risk appears to be negligible. Each "yes" answer scores one point and each "no" answer scores zero points. At the end of the inspection, the points are totalled, yielding a sanitary inspection risk score (Mushi et al, 2011).

A higher risk score represents a greater risk that drinking water is contaminated by faecal pollution from the area immediately surrounding the well (Godfrey et al. 2006; Luby et al. 2008; Vaccari et al. 2009; Parker et al. 2010). It is important to note that although, sanitary surveys can be useful to highlight key aspects of a source's improvement, these may not always be relevant. The method cannot precisely predict water quality but is widely considered to be an essential component of the monitoring of safe water supplies. Hence, selected water facilities were assessed alongside water quality sampling. Table 6.4 shows sanitary risk categorisation, performed according to WHO (1997) thresholds.

Table 6.4: Classification of ROC
(Source: WHO 1997)

Characterisation	**Risk of Contamination (ROC) (%)**
Low	0–30%
Medium	40–50%
High	60–70%
Very high risk	0–100%

6.7.5 Water quality survey

This study thus far has shown that there is a possibility of improving water quality accessed by over 70 million Nigerians using HDW. However, water quality issues and the general perception of HDW remain a major barrier. Changing this notion may require a better understanding of quality and sources of contamination. It provides an informed basis for making a case for HDW in rural communities. For example, Harvey and Drouin (2006) conducted a comparative study on water quality between rope pumps and conventional handpump found that there was no significant difference between the two pump types in terms of microbiological water quality.

50 HDW and 10 Boreholes selected were samples were collected to determine the level of contamination in HDW in order to compare with improved boreholes facilities in the same vicinity. The 10 water samples were purposefully located less than 15m from a sampled HDW. The main parameters of interest were the basic physicochemical which include temperature, pH, conductivity, turbidity and Total Dissolved Solids (TDS).and Bacteriological parameters were total coliform and faecal coliform. The physical parameters were analysed on site while chemical and bacteriological investigation were conducted at the Rural Water Supply and Sanitation Agency (RUWASSA) standard laboratory.

6.7.5.1 Measurement of physical parameters

The physical analysis of water samples was done on the field, pH with a pH meter, conductivity (Micro-semen/cm) and Total Dissolved Solids (TDS) with of YSI EC 300 conductivity meter. Turbidity was tested with a manual Turbid meter. The instrument was

routinely calibrated with up-to-date standards and manufacturer procedures were followed for the determination of all test results.

6.7.5.2 Measurement of microbial parameter

According to WHO (1997), coliform organisms have long been recognised as a suitable microbial indicator of drinking-water quality, largely because they are easy to detect and enumerate in water. The term "coliform organisms" refers to Gram-negative, rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties and able to ferment lactose at 35-37°C with the production of acid, gas, and aldehyde within 24-48 hours. They are also oxidase-negative and non-spore-forming and display β-galactosidase activity.

Samples for microbial analysis were taken from HDW in sterile bottles, stored not exceeding 6 hours in a light proof insulated box containing ice packs with water to ensure rapid cooling and transported to the state Rural Water Supply and Sanitation Agency (RUWASSA) standard laboratory. Indicator bacteria for microbial analysis were faecal coliform (E. coli) and total coliforms. The analysis was done using the multiple tube-most probable numbers technique. The Guidelines for Drinking-Water Quality recommend that faecal indicator bacteria (FIB), preferably E. coli or alternatively thermotolerant coliform (TTC), should not be detectable in any 100ml drinking water sample (WHO,2011).

6.7.6 Direct observations

In the process of administering the data gathering instruments, physical examination of the facilities, surroundings, and household members, were documented. Careful attention to details of events, behaviours, and circumstances is a valuable way to collect data. The data collection included community transect-walks to triangulate information given in the conversations, interviews and surveys with first-hand experience. The method was intended to capture water use, sanitation and hygiene practices. The peak times for HDW are the morning hours before 7.00 am and evening between the hours of 5.00 -7.00 p.m. The right timing is required for the researcher to observe water handling and users' behaviour around HDWs (Oluwasanya, 2009).

6.7.8 Perception surveys

Following the findings in literature and subsequent decisions to explore HDW- self-supply, the rope pump technology and groundwater in the sustainable rural water service delivery, the author in accordance with Robson (2002) which stated that 'To find out what people do in public use direct observation, what they think, feel and/or believe, use interviews, questionnaires or attitude scale', adopted a questionnaire survey approach to capture perceptions of users.

The purpose of the perception survey is to assess user perspective on critical concepts identified in literature that could be important in self-supply rural water service delivery. These include building blocks for self-supply according to Sutton (2007), viability of the rope pump technology based on criteria such as acceptability, durability. affordability, operation and maintenance, and water quality outlined in Nigeria Standard for Drinking

Water Quality (NSDWQ, 2010), and of water sources based on the Dublin principles of water resource management. 50 respondents were interviewed on a one on basis selected based on availability, willing to participate and convenience from initial 96 household respondent contacted at the initial stage of the research. The perception survey questionnaire is attached as appendix E. Detailed findings are discussed in chapter 7.

6.7.9 Key informant interview

A total of 5 informants were interviewed to provide insight into the general condition of rural water supply management in the area. Their selection was based on being stakeholders in the water sector highlighted in Chapter 2. The interview covered includes information on water policy, institutional structure, role and responsibilities, and community water facilities management in the area.

The key informants comprise of two staff of study area LGA water and sanitation unit, a technical officer of Rural Water Supply and Sanitation Agency, a member of water and sanitation committee (WESCOM), an WASH consultant and an academic with speciality in water resource management. The interviews took place in location convenient for the interviewees and lasted an average of an hour.

6.8 Guidance framework validation

According to Bashir (2013) the extent to which research findings can be relied upon depends on the processes conducted in establishing its validity. Validation is the process of assessing the degree to which a measure accurately represents what it purports or is required to measure (Hair et al., 2010). Evaluation is a key part of a framework development process which increases confidence in the framework while making it more valuable (Kennedy *et*

al., 2005). Frees (1996) describes the validation of a framework as the process of assessing and confirming if the proposed framework is appropriate to do what it sets out to achieve. The proposed guidance framework will be validated by requesting stakeholder perception on the relevance of the developed guidance framework to supporting the fundamental drivers of sustainability identified in the research using the Likert scale.

Allen and Seaman (2007) noted that Likert scale is a psychometric response scale primarily used in questionnaires to obtain respondent preferences or degree of agreement with a statement or set of statements. Likert scales are a non-comparative scaling technique and are unidimensional in nature. Respondents are asked to indicate the level of relevance and applicability of framework by way of an ordinal scale of 1-5, (See Appendices: F). Analysis of the validation survey was done using descriptive statistic, and is detailed in chapters 7 and 8.

6.9 Data Analysis

In analysing data collected from a sustainability study, there are many sophisticated data analysis methods that can be used to analyse sustainability factors variables and indicator Lockwood, (2003), however, argued that such statistical analysis techniques fall short of fully conveying details of the data collected and therefore such an approach tends to shift the research focus out of context from the community or household (Schweitzer, 2009) Therefore, simple descriptive statistic techniques, tabular and graphical representation would be sufficient to communicate details of the findings to stakeholders in the water and sanitation sector in Nigeria.

6.9.1 Quantitative data analysis

Quantitative data analysis was conducted using simple descriptive statistic of frequency distribution. Descriptive statistics are used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures. Together with simple graphics analysis, they form the basis of virtually every quantitative analysis of data. In terms of approach, the data were sorted, entered and analysed using the statistical package for social science (SPSS). Descriptive statistics and cross tabulation of relevant variables were generated to discuss findings and relationships.

6.9.2 Qualitative data analysis

Qualitative data is the form of words and/or pictures centred on interactive processes. Involves in-depth detailing knowledge of cases, based on non-causal or inductive theory. The process of analysis starts with themes extraction, to description, interpretations and generalisations from evidence to present a fluid and consistent scenario. The analysis of qualitative data included transcribing of the data to readable text. The transcripts were reviewed to delineate issues relevant to the research questions. The issues were reviewed to extract key insights and explanations using content analysis techniques.

6.9.3 Water quality data analysis

The water samples were analysed and compared with guidelines for drinking water quality determined by Nigeria Standards for Drinking Water Quality (NSDWQ,2007, WHO, 2007) (See table 6.5). Field results are presented in section 7.4.

Table 6.5: Drinking water quality for WHO and NSDWQ (Source: Ndububa and Idowu, 2015)

PARAMETER	WHO		NSDWQ
	Highest Desirable level	Maximum Permissible Level	
Temperature (°C)	–	40	Ambient
Colour (TCU)	6	15	15
Turbidity (NTU)	5	25	5
pH	7.0-8.5	6.5-9.2	6.5-8.5
Total dissolved solids (mg/L)	500	1500	500
Iron (mg/L)	–	0.3	0.3
Chloride (mg/L)	–	250	250
Flouride (mg/L)	–	1.5	1.5
Total hardness (mg/L)	–	500	500
Sulphate (mg/L)	–	100	100
Nitrate (mg/L)	–	50	50
Faecal coliform (per 100ml)	–	0	0
E. coli (per 100ml)	–	0	0
Total coliform count (per 100ml)	–	0	10

WHO (2004) - World Health Organization
NSDWQ (2010) - Nigerian Standard for Drinking Water Quality

6.10 Fieldwork constraints

Culture: Due to the culture and religion of some of the households, it was necessarily to have a female research assistant on the team to collect data in a residential compound where an adult male or unaccompanied outsider would not be allowed free entry into a respondent compound, however, in some instances the researcher was granted access in the company of an adult male household member.

Language: There was difficulty interacting with respondents who could not communicate in English Therefore to avoid misinterpretation of the survey instruments, the research assistants were properly briefed to ensure that all involved understood what each question meant in the local language (Hausa) in order for them to translate appropriately. The researcher's sound knowledge of speaking, listening, reading and writing of the local language was instrumental at this stage.

Lack of motivation: Despite some level of sensitisation in the communities, some household declined to willingly participate in the survey, citing the several data collections that had taken place in the past without any meaningful outcome, direct benefit or improvement in their livelihoods. However, informing them that the exercise was for an academic research encouraged some respondents who initially refused not only to willingly take part, but also to show much interest in the overall study.

Security concerns: There were security concerns in the region due to the activities of an armed militia operating in North-Eastern Nigeria. Many of the residents were apprehensive and security conscious. There was an instance when an alleged imminent attack in the area led to fieldwork being abandoned.

6.11 Quality Assurance

During data collection, the researcher was supported by research assistants. It was ensured that the assistant understood detailed descriptions of interviewing techniques, field procedures, and all sections of questionnaires reviewed thoroughly without unambiguity before embarking on fieldwork. Samples were taken from locations that are representative of the water facility across the study area. In selecting sampling points, each facility was considered such that the samples taken were representative of the different sources from which water is obtained in the area. To ensure a representative data collection sampling points were uniformly distributed throughout study area settlements and population distribution.

6.12 Ethical Considerations

Ethical consideration is one of the most vital aspects of every field research (Bailey, 2007). A credible research design is one that attempts to maximise both validity and reliability of the research process and data collection (Bickman and Ro, 1998). Ethical considerations are necessary to protect the participants and their organisations, gain their confidence and trust, promote the research quality, integrity, and guard against inappropriateness (Farell,2011).

The study was conducted in a way that ensured that confidentiality and integrity of the participants were respected. Participants were fully informed about the aims of the research, and that their participation was on a voluntary basis and that at the end of the research, data collected from them will be destroyed (De Vaus, 2002). To protect the identity of individual respondents, the questionnaires were anonymous. Ethical approval was sought and obtained from the Ethics Committee of the University of Wolverhampton Faculty of Science and Engineering Ethics Committee.

6.13 Chapter Summary

The Chapter presents a research approach and methodology and how this was developed. It attempted to explain how the development process evolved, based on consideration of various research approaches. Discussed various research techniques used and data gathering tools deployed towards realisation of the research objectives. The mixed method approach adopted for the study was considered the most suitable because the research span through social and technical subject areas.

Quantitative data was obtained from water facilities inventory survey; this was aimed at determining the functionality level of conventional water facilities such as handpump and motorised borehole in the study area. This was with a view to compare findings with the level of water facilities breakdown reported in the literature for Nigeria and sub-Saharan Africa region. Household surveys were administered to 96 individuals to represent the social demographic of the area. The information from the household survey provided the basis for exploring the potential of hand dug as sustainable rural water potential. However, the concern and social perception of HDW inspire the need to carry out water quality test and sanitary risk assessment. Hence, 50 HDW and 10 handpump boreholes were sampled for water quality and sanitary risk assessment survey.

The above informed user perception surveys conducted to understand user perceptions of the concepts of Self-Supply, HDW, RPT and CBWRM. Data collected were analysed quantitatively and qualitative to provide useful information, with a view to formulating a guidance framework. Detailed analysis of data collected is discussed in chapter 7.

Chapter 7

7.0 Field investigations, findings and discussions

7.1 Introduction

This chapter presents the analysis of collected data, discussions and findings. Data were obtained from interviews, questionnaires surveys and direct observation. Data collected were recorded, analysed and interpreted in this chapter. Field data were collected and analysed in an iterative pattern, with insights from one stage of the study feeding into another to build up an argument. It is on this premise that the proposed guidance framework presented in chapter 8 was formulated, from which recommendations and conclusions were drawn.

7.2 Water facilities inventory result

A total of 78 inventory of water facilities were undertaken. This is presented in Table 7.1. The surveyed water facilities include handpump, solar powered and motorised boreholes. The result of the inventory shows that water facilities in the study area are 52 % functional, 11% partially functional and 37% non-functional (See Figures 7.1). This result corroborates findings in literature which indicated about 40- 60 % water facilities failure experienced in sub-Saharan Africa discussed in previous chapters. The result supports the argument for the exploration of other alternative options that could result in more sustainable service delivery.

Table 7.1 Summary of improved water facilities inventory

Type of water point	Average depth(d) and depth range	Water lifting device	No of water point n=78
Handpump boreholes	Average depth of 8m, where d ≤ 30	Handpump Boreholes – Indian Mark III	74
Solar powered boreholes	Average depth = 18, where d ≥10 ≤ 50	Motorised submersible pumps, solar pumps,	1
Motorised diesel engine powered boreholes	Average depth = 18, where d ≥10 ≤ 50	Motorised submersible pumps, solar pumps	3
Total			n=78

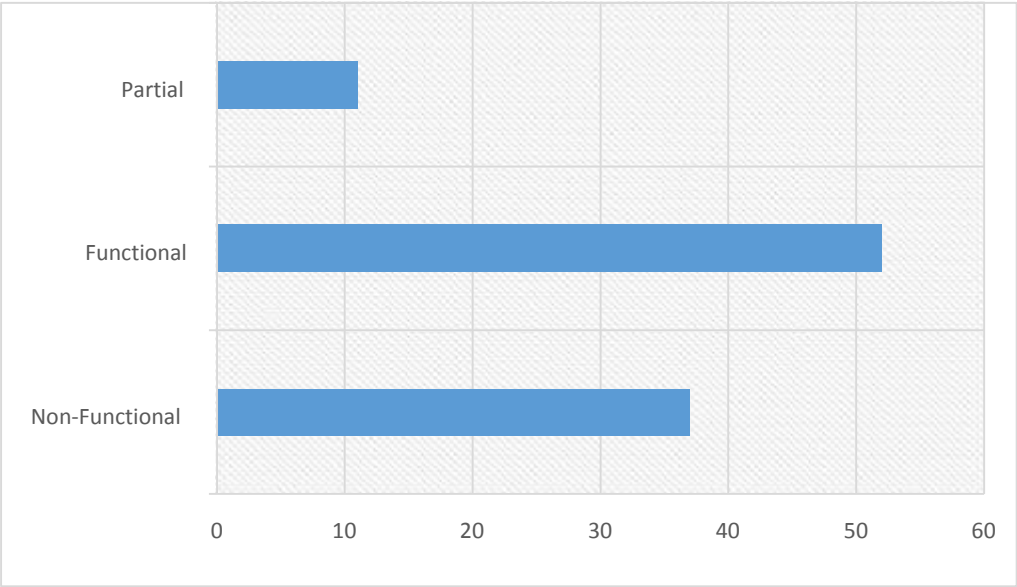


Figure 7.1 Functionality status of water facilities

7.3 Households survey result

This section presents the result of a total of 96 household respondents interviewed in the study. Findings from the survey provide useful insight on residents social-demographic information as well as water supply characteristics using questionnaires survey (see appendices D)

7.3.1 Households social-demographic profiles

As indicated in Table 7.2, the social demographic result indicates of the 96 respondents, 38% home owners, 43% are co-owners while 19% are tenants. However, about 90% of the respondents claimed to poor. The result also show that majority of households are farmers. The social economic condition of the household in the area support the need to explore less expensive and affordable water supply option that household conveniently afford and managed

The position of the respondent indicates that 54% husbands, 38% wives and 8% other adult member of household. Having more than halve of the household respondents as husband could point to a strong lining towards male dominated conservative structure of the society. But studies have shown that women and girls are more likely to burden of supply to the household than men. Thus, in a search for a sustainable water services provision, extra effort must be made to reach more women and than men in the study area. Therefore, in finding solution to unsustainable water facility, this social cultural aspect of the society must considered as an integral factor.

The level of education of the respondents was found to be 47% Islamic education, 27% primary education, 16% secondary education, 4% higher education and 6% do not have any formal of education. The study found that 56% the respondents to be farmers,14% claimed to be self-employed, 7% civil servant, 9% traders, 3% students and 11% unemployed.

Table7.2 Socio-Demographic Characteristic

Socio-Demographic Characteristic	Percent (%) n=96
Status of household	
Owner	38
Co-owner	43
Tenant	19
Position of Respondent in Household	
Husband	54
Wife	38
Adult member of household	8
Level of Education	
Primary	27
Secondary	16
Higher	4
Islamic Education	47
None	6
Occupation of Respondents	
Unemployed	11
Student	3
Farmer	56
Trader	9
Self-employed	14
Civil servant	7
Economic status of household	
Very poor	18
Poor	71
Rich	11

7.3.2 Important communication channels in the study area

The study revealed that radio was a major channel of information dissemination in the study area, 24% of the respondents indicated radio, 22 % traditional communication channels and 18% religious centre were also considered good sources of information in addition to the 12% use of mobile phone. Details are presented in Table 7.3. These communication channels identified by respondents represent the most effective avenue for social mobilisation and communication required for any intervention to succeed in rural communities. The channels can be utilised to promote mass participation in sustainable water supply model or approach.

Table 7.3 Channel of communication in the study area

Channel of communication	Percent % n=96
Radio	24
Traditional channels	22
Religion centres	18
Telephone/Cell phone	12
Clinics	6
Posters	4
Schools	4
Television	5
Newspapers	4
Others	1

7.3.3 Community institutional structures

The study revealed that 41% respondent considered religious places of worship such as the church and mosque as important community social structures. 19% indicated youth organisation and 10% mentioned community development associations, others include

women groups, traditional rulers, cooperative societies and others presented in Table 7.5. Local institutions play vital roles in the sustainable development of the communities.

Table 7.4 Main institutional structures in the study area

Institutional structures	Percent (%) n=96
Religion organization	41
Youth groups	19
Community Development Associations	10
Women Societies	8
Traditional rulers	8
Cooperative Societies	6
Others	1

Promoting any concept of sustainable water service delivery through religious bodies may encourage an extensive acceptance and adoption among households. Thus, engaging community structures could foster acceptability and a sense of ownership in an alternative approach toward sustainable water service delivery.

7.3.4 Household access to water supply

Respondents indicated multiple access to improved water sources in the area as shown in Figure 7.2. The main water sources and facilities include, HDW, handpump boreholes, small-town-motorised schemes, rainwater harvester and protected spring. About 50% of respondent identified improved HDW as a reliable water supply source.

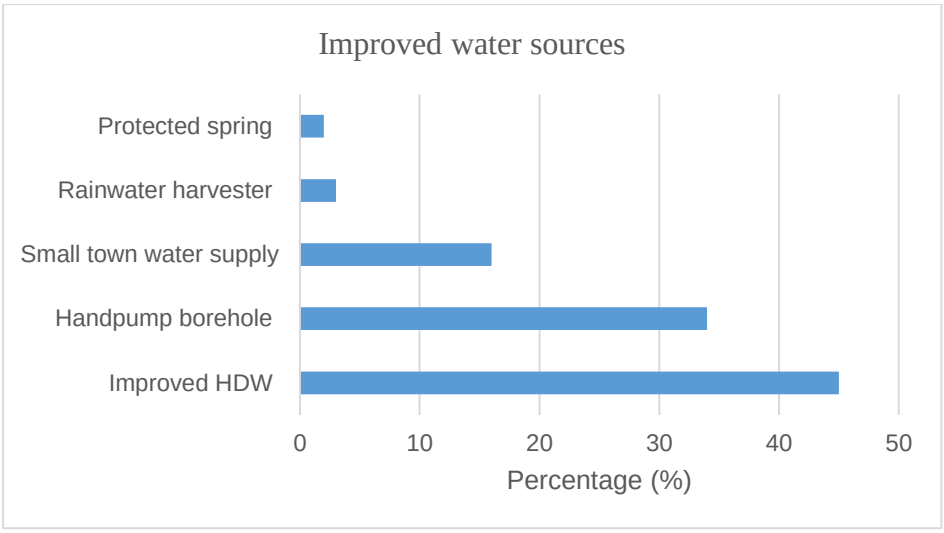


Figure 7.2 Response on access to improved water sources

Figure 7.3 shows the result of respondents access to some unimproved water sources. These sources include traditional HDW, streams, rivers and ponds. This is presented in Figure 7.3. The result show that resident in the study area access to improved and unimproved water sources suggest a considerable use of HDW as vital very their main water source. Therefore, and improvement on the capacity of HDW could provide safe and sustainable access to many in the study area.

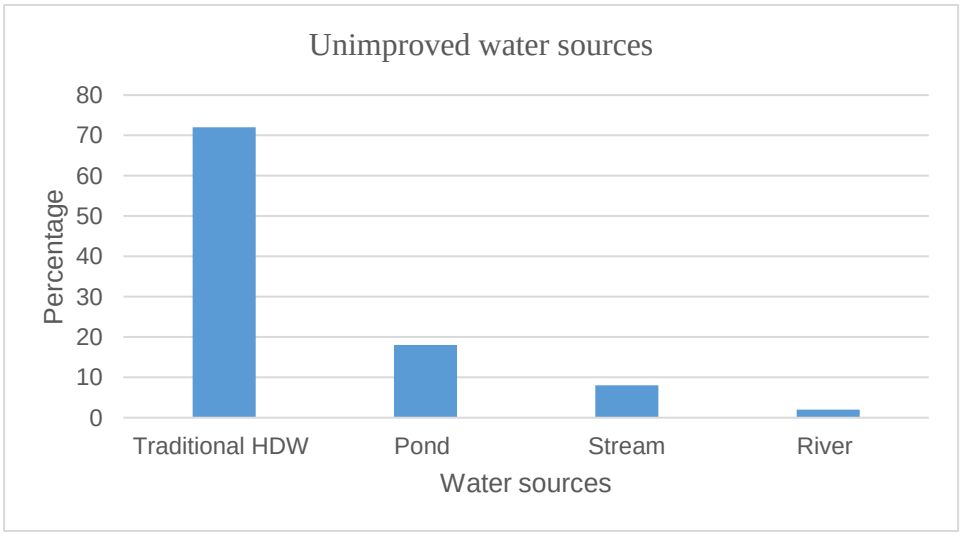


Figure 7.3 Responses to unimproved water sources

7.3.5 Water use

Figure 7.4 indicate households main purposes for sourcing water is 25% drinking, 23% cooking, 22% washing, 16% bathing, and 14% animal feeding. The result show that priority is given to the use of water for drinking over other uses. 1 out of every 4 litres is use drinking. It is therefore important that every water sources are secured from all forms of physical or biological contamination which was discussed as a major barrier to accepting HDW as safe water source.

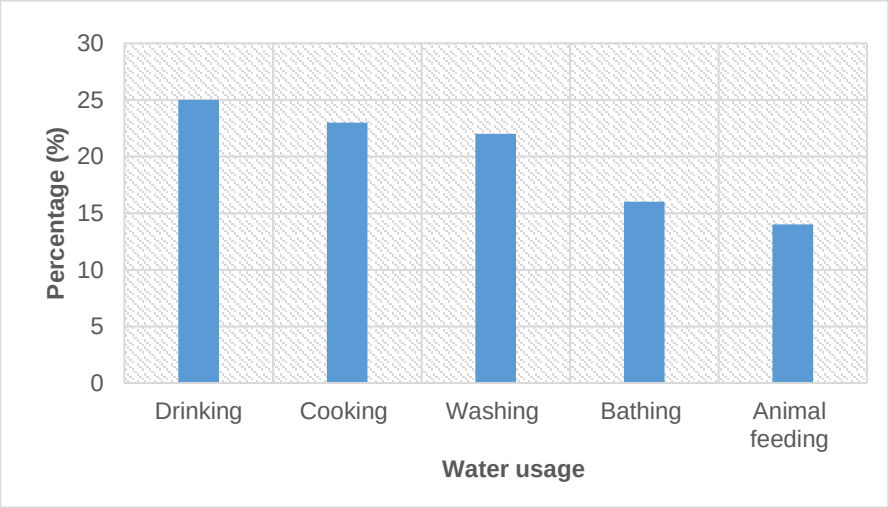
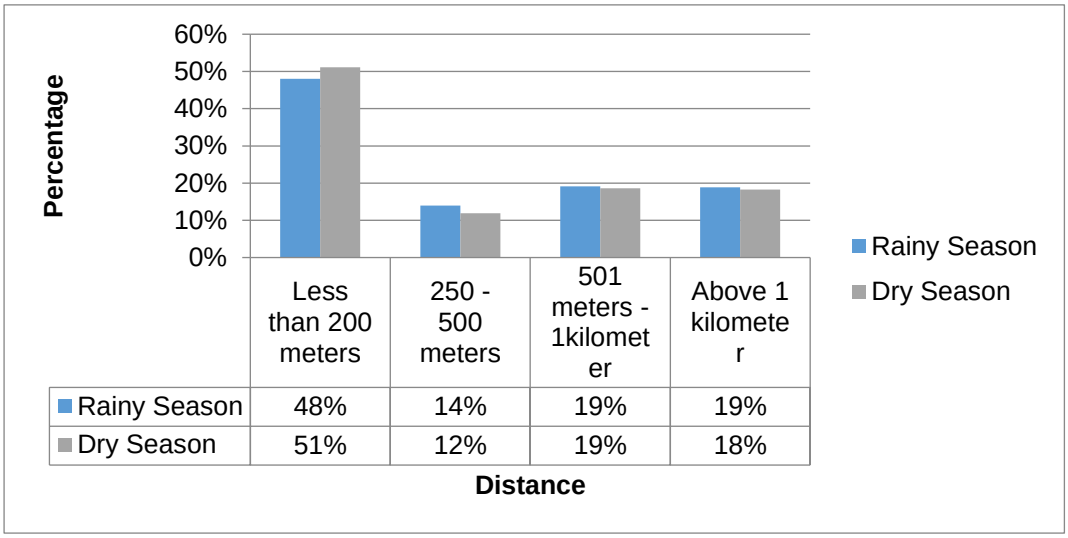


Figure 7.4 Purposes and use of water source

Respondents consider most of the water sources in this study as 86% reliable during rainy season and 69 % reliable in the dry season. This could be attributed to perennial water supply obtainable from HDW and/or boreholes in the area. As earlier discussed in chapter 5, the area is endowed with high water table which could support almost year-round water supply from HDW/boreholes. The is support the idea of exploring HDW with RPT in the study area to improved water supply service sustainability.

7.3.6 Distance to water sources during rainy and dry seasons

The study found the distance between water sources during the rainy and dry season to be similar. Having to trek long distance to obtain water is not a problem for most households in the study area. Figure 7.5 indicated that less than 55% of the respondents indicated that they travel less than 200 metres to get improved water supply either in the rainy or the dry season. This finding further buttress the fact that HDW remains a foremost water supply source.



	Less than 200 meters	250 - 500 meters	501 meters - 1kilometer	Above 1 kilometer
Rainy Season	48%	14%	19%	19%
Dry Season	51%	12%	19%	18%

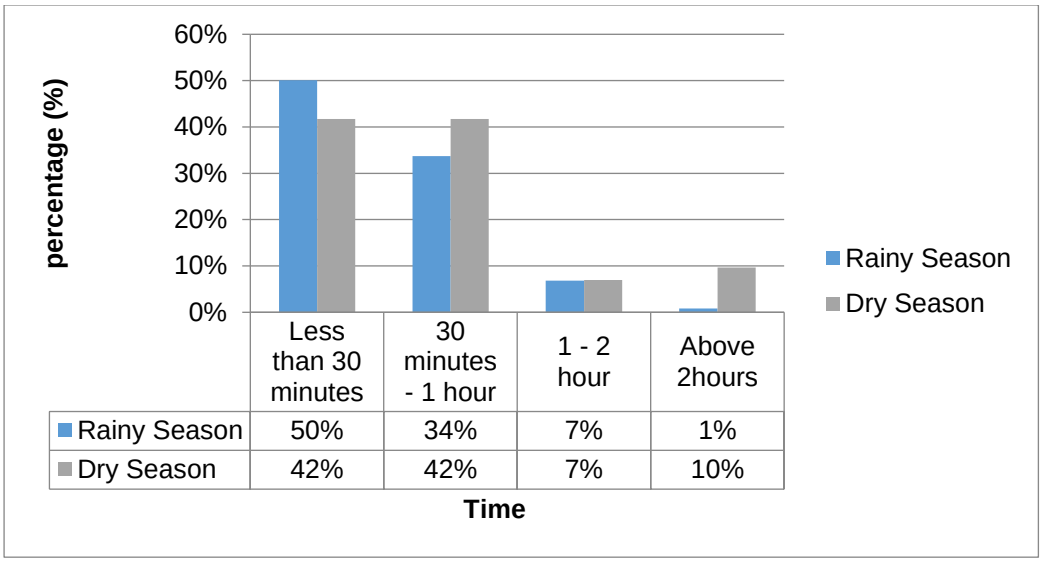
Figure 7.5 Distance to water sources during rainy and dry seasons

About 76 % of the 96 household respondents indicated that they collect more than 35 litres of water per day either in the rainy season or dry season, 15% indicated they collect less than 20 -35litres, while 5% collect less than 20 litres per day either in the rainy or dry season. The high percentage of respondent collecting more than 35 litres per day could suggest the closeness of hand dug well to a household in the area. Because, in many rural communities in Nigeria, water is transported often time from the source to the household

by an individual, this could be either on the head or held by hands. Therefore, distance travelled to fetch water could determine the amount of quantity of water to be collected at a single visit to a water facility.

7.3.7 Time taken for roundtrip to water sources during dry and rainy seasons

The study found that the average time taken to a water facility varies from less than 15 minutes to above 2 hours. There is little or no difference between in time taken to water sources in the dry and rainy seasons. Only about 10% take more than 2 hours for return trip to an improved water source in the dry season. This is presented in figure 7.6



	Less than 30 minutes	30 minutes - 1 hour	1 - 2 hour	Above 2hours
Rainy Season	50%	34%	7%	1%
Dry Season	42%	42%	7%	10%

Figure 7.6 Time taken for round trip to improved water source

7.3.8 Management of water supply facility

From the analysis, 79% the respondents indicated that they have contributed in cash or in kind to the initial cost of water facility construction, 21% indicated they did not make any form of contribution to the project. Out of those who made contribution 60% contributed in

cash while 40% contributed in kind. On the question of whether there is a group responsible for taking care of the water facility in the study area, the study found out that 79% indicated there is a caretaker group, 14% said there is no caretaker and while 7% do not know. Out of those aware of the management group 42 % indicated that the caretakers have performed their duties effectively, while 55% responded that the managers of the water facility are not effective and 3% do not know.

The study also found that women participation in water facility management is low. 26% responded that women are involved but 31 % responded that women are not involved while 43% do not know whether women are involved.

The respondents indicated that the improved water points would have experienced some form of breakdown in the last one year, 91% indicated that the water facility has broken down while 8% said no and 1% of the respondents do not know. Respondents indicated they do not make payment for the repairs when the water facility break down. 30% pay for repairs while 70% do not pay.

On time taken to carry out any repair on water facility has a fault, 23% of the respondent indicated repairs are carried within a week, 57% indicated repairs are carried out within a month week as shown in figure 7.7. The less than a quarter of the respondent that indicated repairs are carried out within one this week could strongly indicate poor operation and maintenance of community based water facility. There is a likelihood that this may not be the case if the facility is owned by an individually or group of households.

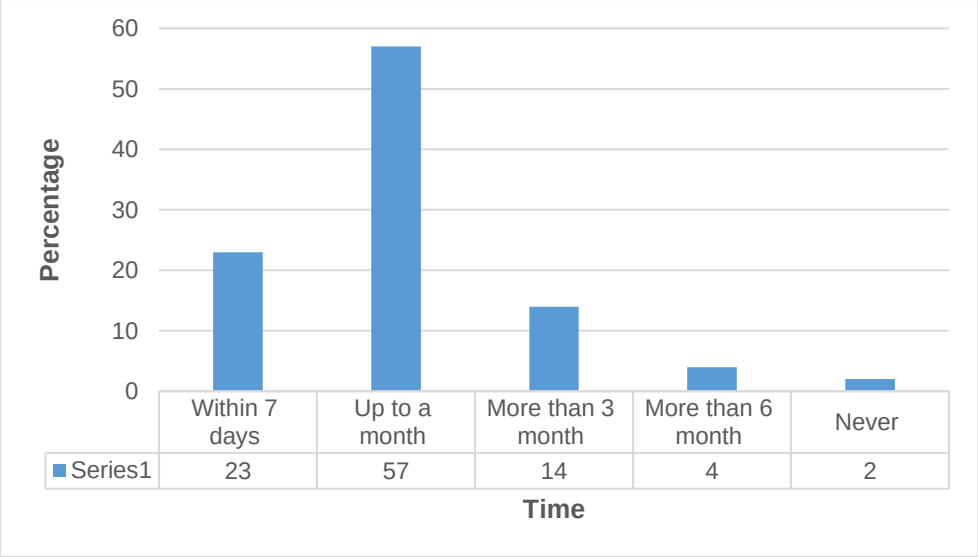


Figure 7.7 Repair of water facility

7.4 Household access to sanitation facilities and hygiene education

7.4.1 Access to toilet facilities

This study found that 97 % of the households have access to latrine and just only 3 % do not own a latrine. Of the 3% that do not own a latrine, 60% indicated they lack financial resources, 20 % stated that it is not useful, 20% use communal latrine. This is presented in figure 7.8.

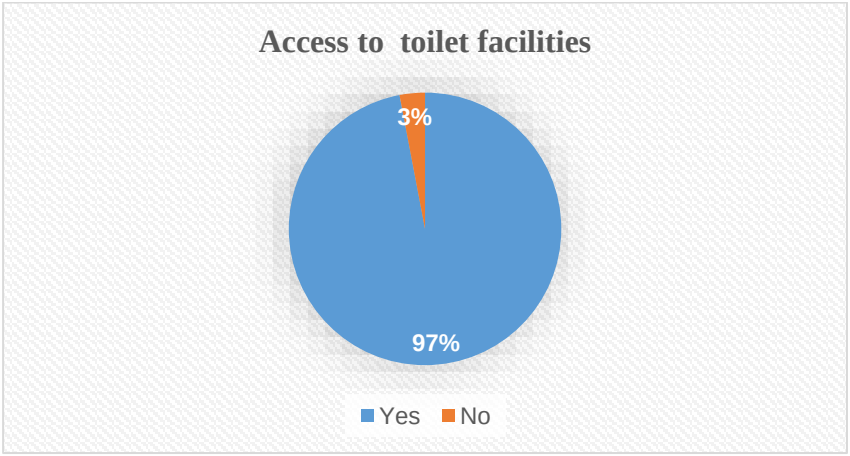


Figure 7.8 Access to latrine facilities

7.4.2 Ownership of latrine

81% indicated they own a latrine, 14% use shared latrine while 5% claimed to use a public toilet. The study also found that pit latrines were 84%, Soak away pit 11% while only 5% indicated they use pour flush toilets. Most households live in a compound often not more than 250m^2. The houses have pit latrine less than 20m away from water source, which this is less WHO minimum recommended distance of 30m between water sources and faecal contaminant.

The studay also revealed poor hygiene activities around some wells, domestic activities such as laundry, bathing and washing were observed at some location. The understanding of the latrine usage when exploring self-supply HDW is important, as this could impact on the quality and safety of the ground water. The distance between the toilet and HDW is as pertinent as well as the quality of HDW construction (See section 7.5 and 7.6)

7.4.3 Household solid waste disposal

The study found that 62% dispose household solid waste around the compound, 21% pack and burn in a pit and 8% dispose of inside the compound, 7% dispose of refuse in the community dump site, while 2% disposes of waste in the incinerator presented in Figure 7.9.

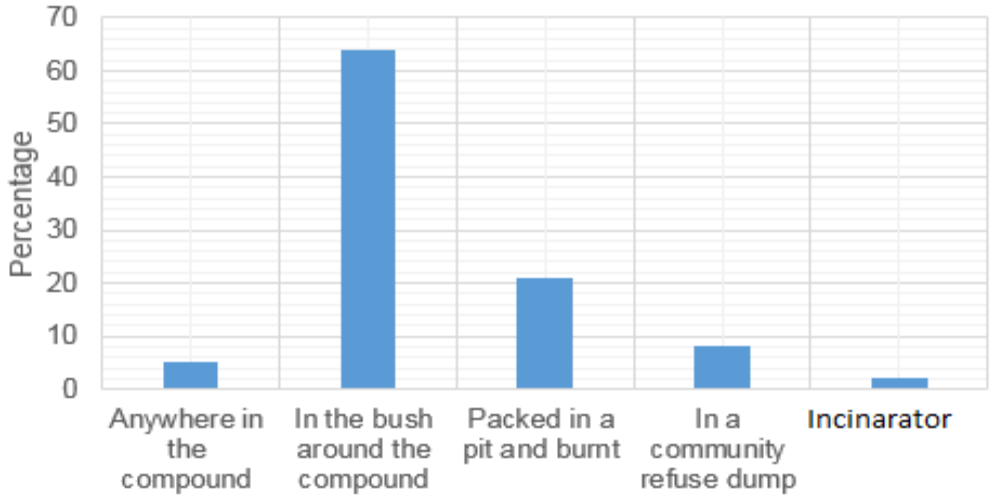


Figure 7.9: Household solid waste disposal

The manner solid waste generated within the household dispose of could have implications for water sources in the area. During the rainy season, the waste could be flooded and as result pollute surface water or leach into groundwater. Therefore, a community-based and household water and environmental management framework may be required to protect water sources

7.4.4 Access to household hygiene information

The study revealed that 97% of respondent have had a form of hygiene awareness, training or education while 3% claimed they have not heard any hygiene messages. The study further revealed that the most prevalent source of hygiene education to household members is through the community health officials and radio programmes. Discussions with respondents revealed that most hygiene education takes place at the community level, encouraging men, women and children to practice good hygiene such as the use of latrines handwashing at critical times, proper solid waste disposal and safe drinking water storage. However, the level of awareness expressed does not reflect the result obtained in section 7.4.2 and Table 7.6. Both results suggest low-level hygiene amongst household and

facilities surveyed. This suggest a need to improved hygiene education and reorientation on poor hygiene practices and its linkages to water supply, health and wellbeing.

7.4.5 Household awareness of climate change

The level of awareness and knowledge of climate change and it potential impacts on water sources and water supply is very low. The study revealed a lack of awareness of climate change among respondents. Only 21% of household respondents are aware of climate change while 76% are not aware and 3% do not know (See Figure 7.10). The result shows a low-level awareness on climate change and environmental variability amongst respondents. A discussed in chapter 5, it is important that water users have basic understanding of climate change as it relates, population growth, water demand and water resources management.

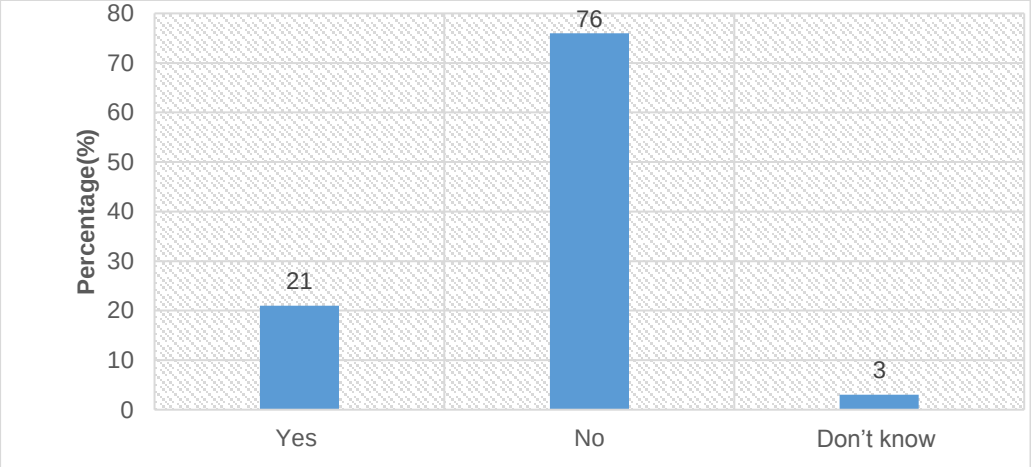


Figure 7.10: Perception of climate change

7.5 Sanitary risk assessment result

Table 7.5 shows results of sanitary risk assessment survey (see appendices D) conducted for 50 HDW. Results indicated some of the important risks to HDW in the study area included; presence of latrine within less 10m from the HDW, animal breeding, farming activities, waste dump site, poor sanitation situated too close to HDWs as well as the quality of well-head construction. It was also observed that many of the drainage around HDW could constituted a sanitary risk. the results strongly suggested that the quality of the water in HDWs was likely to be affected by external sources of contamination as well as faecal pollution.

Table 7.5 Sanitary survey result

	Sanitary risk inspection question n=50	Number of "yes" responses	Response frequency (%)
1	Is there a latrine within 10m of the well?	44	88%
2	Is the nearest latrine uphill of the well?	38	76%
3	Is there any other source of pollution within 10m of the well? (E.g. animal breeding, cultivation, road construction and industries)	39	78%
4	Is the drainage faulty allowing ponding within 3m of the well?	39	78%
5	Is the drainage channel cracked, broken or need of cleaning?	31	62%
6	Is the cement floor less than 2m in diameter around the top of the well?	40	80%
7	Does spilt water collects in the apron are?	29	58%
8	Are there cracks on the cement floor?	27	54%
9	Is the lifting system loose or not working properly?	38	76%
10	Is the well cover slab cracked and unsanitary?	32	64%

Table 7.6 shows the summary of 50 HDW sanitary risk assessments reports. All the 9 public HDW surveyed were found to be of very high risk, 25 communal HDW were high

risk, while some individual and communal Wells were medium risk and 6 low risk were boreholes and some individual HDWs.

Table 7.6 Sanitary risk assessment of water facilities

(%)Range of Sanitary risk	Description of Risk	No of HDWs	Percentage (%)
	n = 50		
0–30	low	6	12
40–50	medium	14	28
60–70	high	21	42
80–100	very high risk	9	18

A field observation revealed that, HDW can be broadly categorised under the following heading of ownership such as: individual, communal or public HDWs (See table 7.7). These categories could be associated with the ease of access, quality of HDW construction, which minimises the risk of external contamination and the number of people using the well.

The study also found that privately operated HDW have regulated use, and are usually located within a compound. Many individually owned wells are in have good hygiene condition, have properly developed well-head, and dedicated water lifting device. On the other hand, communal and public HDW tend to have less of the quality elements listed. This finding suggests that self-supplied hand-dug could minimised the risk of contamination of hand-dug wells mention in chapter 5 as perceived to be of low water quality. This support argument could support the use of HDW in sustainable water service provision.

Table 7.7 HDW characterisation

Ownership	Ease of access to users	Protection from external contamination	No of HDW surveyed
	n=50		
Private wells usually located within a compound	Monitored-restricted access	Well-protected	11
Communal or group of household well is usually located in a compound family or secured clan access	Relatively accessible to group people or cluster of households	Fairly-protected	25
Public and community own wells are government	Freely accessible to all	Poorly-protected	9

Figure 7.11 shows an uncovered community HDW in Dass, a line and rubber bucket being used, with line touching the ground which can result in contamination. Therefore, the sanitary risk assessment result suggests a need to reduce HDW contamination due to external exposure, improved hygiene practices around water facilities and introduce comprehensive management measures to protect wells from ground water contamination.

Figure 7.11: Uncovered community HDW with line and rubber drawer being used

7.6 Water sample analysis

The result of the sanitary risk assessment discussed in section 7.5 only provides an indication of potential sources of pollution. To ascertain the actual level of pollution, it was necessary to conduct a water quality test for each of the HDW test risk assessed.

The samples taken from HDWs in Dass is presented in Table 7.9 and shows significant values of total coliform and faecal coliform contamination while samples taken from handpump and Boreholes (See Table 7.10) indicated very low level of microbial contamination. The distance of the HDW from latrine, poor sanitation wells, proximity to animal drinking trough, as well as contaminated water lifting system level could be responsible for the level of total coliform and faecal coliform bacteria in HDW water samples analysed.

Table 7.8: HDW quality test result

Water source code	Location coordinate		T (^{0}C)	Conductivity (us/cm)	TDS (mg/l)	pH	T (cfu/100ml)	F cfu/100ml)
	Latitude (N)	Longitude (E)						
W1	12.18913	010.32109	39.9	2011	1005	7.4	310	154
W2	12.19449	010.37402	37.1	760	380	7.1	320	187
W3	12.17118	010.38880	37.5	1015	580	6.9	415	230
W4	12.22182	010.41112	38.5	1013	560	7.0	402	173
W5	12.22121	010.41634	39.4	830	410	6.7	301	201
W6	12.23175	010.43643	39.0	1093	970	6.9	380	98
W7	12.17371	010.42421	39.0	1079	890	7.4	510	232
W8	12.10011	010.48382	32.8	656	328	7.1	411	201
W9	11.96570	010.74823	36.9	1033	660	7.4	390	91
W10	11.96383	010.74660	37.7	830	410	7.3	301	107
W11	11.96447	010.74450	37.8	2085	1042	6.8	432	201
W12	11.96647	010.74344	37.8	700	350	6.9	410	203
W13	11.96573	010.74174	37.2	1003	520	7.5	330	122
W14	12.12931	010.53379	36.6	3082	1091	7.0	415	232
W15	12.05112	010.50633	37.7	2063	1031	7.0	560	254
W16	11.93800	010.63724	38.2	260	130	7.2	210	87
W17	11.93778	010.64015	36.0	680	340	7.2	230	76
W18	11.93830	010.63568	37.4	380	190	7.3	102	34
W19	11.93936	010.63508		244	122	7.2	110	54
W20	11.93551	010.63533	35.9	580	290	7.8	330	122
W21	11.88397	010.80918	38.4	750	370	7.7	401	211
W22	11.88143	010.80787	37.6	3083	1092	7.2	360	143
W23	11.88020	010.81102	37.6	3083	5069	7.0	501	244
W24	11.88166	010.81046	39.5	5069	2084	7.6	302	89
W25	11.88169	010.81037	38.3	380	190	7.5	410	206

Table 7.8: Continued

Water source code	Location coordinate		T (^{0}C)	Conductivity (us/cm)	TDS (mg/l)	pH	T (cfu/100ml)	F cfu/100ml)
	Latitude (N)	Longitude (E)						
W26	11.34250	010.69372	38.6	690	340	6.8	270	100
W27	11.48117	009.91839	38.8	800	400	6.7	620	233
W28	10.02203	009.53162	37.2	500	250	6.6	310	103
W29	10.02135	009.53224	34.4	2047	1023	6.9	410	223
W30	10.02059	009.53248	36.0	590	290	7.0	1234	365
W31	10.02065	009.53200	36.5	540	270	7.6	1466	276
W32	10.02265	009.53011	36.6	320	160	7.2	302	109
W33	09.97466	009.50811	36.1	1022	610	7.5	352	100
W34	09.97485	009.50808	35.5	990	490	7.3	157	96
W35	09.98509	009.51019	36.9	440	220	7.1	208	88
W36	09.99748	009.52030	36.4	700	350	7.3	215	101
W37	09.99605	009.52284	36.4	770	380	6.8	301	132
W38	09.99911	009.51629	37.0	1021	610	6.5	292	101
W39	09.99827	009.51636	37.1	690	350	7.1	224	100
W40	09.99849	009.51602	34.3	3048	1074	7.4	401	200
W41	10.00145	009.51585	33.1	3090	1095	7.0	424	211
W42	10.00212	009.51501	32.4	2028	1014	7.1	232	103
W43	10.00307	009.52002	35.8	230	110	7.0	409	221
W44	10.03114	009.55661	36.3	260	130	7.5	332	166
W45	10.09302	009.55386	37.4	290	150	7.2	345	160
W46	10.09305	009.55388	37.6	170	80	7.3	420	202
W47	09.99871	009.51609	37.5	310	150	7.1	321	166
W48	09.99874	009.51610	37.7	330	170	7.5	235	98
W49	09.99871	009.51612	38.4	130	60	7.0	401	207
W50	09.99869	009.51610	36.8	310	150	7.4	367	133

Table 7.9: Borehole water quality test result

Water source code	Location coordinate		T (^{0}C)	Conductivity (us/cm)	TDS (mg/l)	pH	T. (cfu/100ml)	F. cfu/100ml)
	Latitude (N)	Longitude (E)						
BH 1	12.18914	010.32108	26.4	288	250	7.1	0	0
BH2	12.19447	010.37400	26.7	434	217	6.8	0	0
BH3	12.17119	010.38870	27.4	236	118	6.9	0	0
BH4	12.22184	010.41122	25.4	300	150	7.0	0	0
BH5	12.22128	010.41638	26.0	286	143	7.2	0	0
BH6	12.23171	010.43645	25.8	366	138	7.1	117	10
BH7	12.17370	010.42428	27.4	190	95	6.5	0	0
BH8	12.10021	010.48392	26.2	220	110	7.3	0	0
BH9	11.96550	010.74828	26.6	263	306	7.4	165	23
BH10	11.96380	010.74661	26.1	232	183	7.1	0	0

Most of the physical characteristics measured are within the WHO and NSDWQ acceptable limit (see Table 6.5). Conductivity and TDS values measured are high in some of the HDW water samples. However, these parameters have no health implications. The water quality tests and sanitary risk assessment results in Table 7.7 suggest that protecting the HDW from external sources of pollution will greatly enhance water quality. Therefore, to maximise the potential of HDWs towards water service delivery, careful attention must be given to the superstructures, water lifting device, sanitation and hygiene practices around the HDW.

7.7 Respondents perception on principles of self-supply

Table 7.10 shows the result of household perception on the principles of self-supply towards self-supply in the study area.

Table 7.10 Respondents perception on principles of self-supply

Principles	Strongly agree	Agree	Overall agreement	Uncertain	Disagree	Strongly disagree	Overall disagreement
	n = 50						
Technical options	6	39	90%	0	4	1	10%
Access to finance	11	32	85%	0	5	2	15%
Private sector involvement	3	42	85%	0	1	6	15%
Enabling government policies	0	4	08%	0	23	23	92%

7.7.1 Technical options

90% of the 50 respondents indicated that the groundwater sources available in the study area inform the technical basis for digging a well. Discussions with some respondents revealed that many of wells were sited without any form of environmental assessment or geological survey. It based on personal intuition and/or convenience.

This suggests that residents are aware of groundwater potential in the area. The HDW depth ranged between 10-20m with an average depth of about 8m. The HDW is the most convenient technical option in the area. Therefore, there is need for an approach that can enhance the technical viability of the HDW, particularly to help overcome challenges discussed in section 5.3.4.

7.7.2 Access to finance

85% of the 50 respondents indicated that their capacity to procure a HDW the most important determent for the decision to undertake a self-supply. According to some respondents main sources of finance were personal savings. other sources such as a bank or private loan is difficult to access. Discussion with respondent revealed that the cost of constructing a HDW in the areas ranges from between $200- $800. The cost of the well is dependent on the depth to water table, social status of the client and contractor engaged. This suggests that household quest to meet their own water demand and the challenges of frequent breakdown of community water facilities could be the motivation to invest in self-supply.

Further discussion, reveal that accessing bank or cooperative loan in the area is very difficult, however, resident take advantage of locally arranged interest free group contribution called ‘adashe’ as viable means of raising fund to finance personal projects such HDW. Therefore, exploring a financial mechanism locally available to household and community towards self-supply would support sustainable water service delivery.

7.7.3 Private sector involvement

85% of the 50 respondents indicated that there are reliable local artisans that can undertake HDW construction in the study area. However, the area lacks organised private sector dedicated to professional HDW construction. Nonetheless, discussion with respondents reveals it only takes a few days to less than two weeks from procurement of local diggers to completion depending on the ground condition. Further discussion revealed that different arrangement may be required with bricklayers to line the well. To maximise the use of HDW toward sustainable service delivery, there needs to be greater social marketing of

both the use of an improved HDW as well as the skills require to deliver standardised self-supply.

7.7.4 Enabling policy environment

92% of the 50 respondents claimed government policies have no bearing on their decision whether or not to develop HDW. There seems to be no enforceable guidelines for HDW design and construction or minimum training or skill required of HDW contractors, artisans or local diggers. The poor policy environment seems to have created and engendered wide spread of unregulated HDW practices in the area.

The above findings suggest that although self-supply could provide an independent a*n*d reliable domestic water supply as an alternative to poor, inefficient and unsustainable improved community managed water facilities. The viability of this can be greatly enhanced by introduction of an appropriate policy framework. Therefore, attention must be given to issues of local water resources management at a policy level as users explore HDW towards sustainable water service delivery.

7.8 Respondents perception on the viability of the rope pump technology

This section presents findings on the viability of the RPT based on respondent perception on the viability of rope technology on private and public HDW. Table 7.11 and Table 7.12 and Figure 7.12 presents summarised of the findings.

Table 7.11 Perception on the viability of the rope pump technology in private use.

Perception on the viability of rope pump in private use	Strongly agree	Agree	Overall agreement	Uncertain	Disagree	Strongly disagree	Overall disagreement
	n = 50						
Acceptability	20	23	85%	0	2	5	15%
Durability			77%	0			23%
Affordability	12	28	80%	0	4	6	20%
Operation and Maintenance	3	25	60%	0	13	7	40%
Perception on water quality	10	10	40%	0	20	10	60%

Table 7.12 Perception on the viability of the rope pump technology in public use.

Perception on the viability of rope pump in public use	Strongly agree	Agree	Overall agreement	Uncertain	Disagree	Strongly disagree	Overall disagreement
	n = 50						
Acceptability	8	12	39%	0	10	20	51%
Durability	4	16	40%	0	11	19	60%
Affordability	12	28	80%	0	4	6	20%
Operation and Maintenance	9	30	78%	0	10	1	22%
Perception on water quality	8	10	35%	0	22	10	65%

Figure 7.12: User perception on public and private rope pump use on HDW

7.8.1 Acceptability

Rope pump technology was rated 85% and 39% for private and public use respectively. Further discussion suggests that acceptance could be attributed to the convenience, tidiness and an improvement the pump provides, when compared to the traditional line and bucket. Some of the public HDW users expressed dissatisfaction with the device and suggesting the community deserved something better. Some respondents consider the use of the handpump or motorized borehole as a more progressive development and do not see the rope pump as such. Therefore, there is an indication that rope pump would be appreciated much more in private use.

7.8.2 Durability

77% of the private HDW respondents considered the rope pump as durable water lifting device compared to only 40% public HDW users. The sharp contrast here can be related to the breakdowns experienced by people using the device in the community. High user numbers resulting in wear and tear often make the RPT mounted on a public well breakdown easily. The situation could be responsible for low level of acceptance of the technology for public use. This suggests that the technology is suitable for household self-supply where a handful of people are responsible for the use and maintenance of the facility.

7.8.3 Affordability

80% of the 50 respondents indicated that the rope pump technology is affordable. The device at time of the field work was estimated to cost about $250 per unit per pump head excluding transportation, installation and other accessories. There is consensus on the affordability of this technology for private and public use, when compared to the other conventional pumps.

7.8.4 Operation and Maintenance

More than 60% public and 78% private users agreed that the pump is easy to operate and maintain compared to other advance technology. There is a consensus among respondents that rope pump could be repaired locally. According to respondents the operation and maintenance of rope pump required minimum skills, spare parts could be source locally, hence requiring short turnaround time.

7.8.5 Perception on water quality

40% and 35% out of the 50 respondents perceived that the RPT could improve water quality both in private and public use respectively. The percentage of respondents on the impact of installing a rope pump on HDW may have been affected by the general notion of the poor quality of water from HDW. Discussion with HDW users revealed that majority of them do not use HDW water for drinking purposes but considered it suitable for any other purposes. Drinking water is often supplemented by bottled or sachet water, otherwise known as 'pure water' in Nigeria. This situation can result in less attention given to the protection of water sources in the area, particularly with respect to the use of groundwater.

The findings on viability of rope pump adoption suggest that the technology could be water service delivery option. However, it is not suitable for large populations and would not withstand wear and tear from frequent use which may lead to recurrent breakdown. Nonetheless, the technology would benefit a household or small group of people living together. The overall user perception of RPT suggest it would benefit private households or groups of households rather than for the whole community.

7.9 Water user perception on the application of the Dublin principles in CBWRM

This section presents findings on the perception of respondents on community local water resource management based on the Dublin principle. As discussed section 7.4.5 of the household survey suggests a lack of awareness on the issues of climate change and its impact on local water resources and it potential impact on water sources in the area. The idea of CBWRM is to create awareness, promote ownership and responsibility of safeguarding water sources and groundwater resources in the community and household. Figure 7.13 and Table 7.13 shows respondent perceptions based on Dublin principles.

Table 7.13 Respondent perception on the concept of CBWRM

Principles	Strongly agree	Agree	Overall agreement	Undecided	Disagree	Strongly disagree	Overall disagreement
	n = 50						
Water as finite resources subject impact of population growth and climate change	9	32	82%	0	9	2	18%
Stakeholders Participatory approach	13	36	98%	0	1	0	2%
Increase the recognition of the role of women	8	22	60%	0	6	3	40%
Water as an economic good	4	20	48%	0	21	5	52%

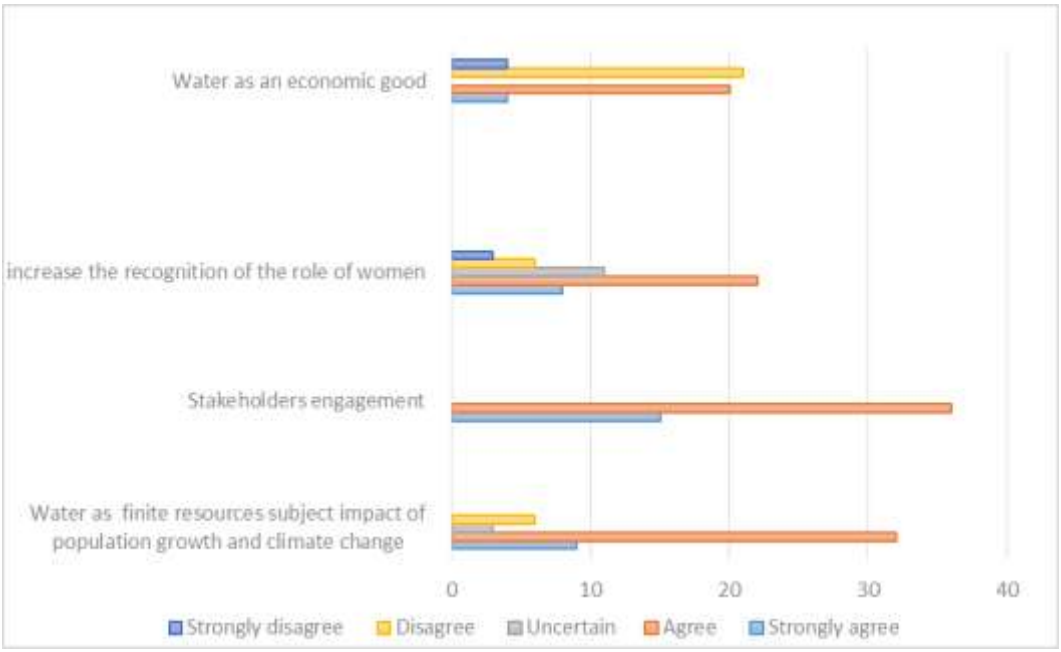


Figure 7.13: Respondent perception on Dublin principles applications

Respondents agreed that fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. The results indicated an overall agreement rating

of, 82%. A respondent also agree that development and management should be based on a participatory approach, involving users, planners and policymakers in the study area with an overall agreement of 98%.

The study found an overall respondent agreement of 60% on the need to recognise and increase the roles women can play in the provision, management and safeguarding of water resources. The result corroborates response received from the household survey in section 7.2.5 which indicated low women participation in water facility management. The observed male dominated and traditionally conservative nature of the study area could be linked to the perception. There is need to create more awareness among stakeholders in the area on need to raise women engagement in water service delivery and water resource management.

The idea of treating water as an economic good received a 48% overall level of agreement. Water is considered a natural gift of nature and treated as social benefit from government in the study area. To change this perception, stakeholders must raise awareness on the need to recognise water as a public good that has social and economic value in all its competing uses. Further discussion with respondents suggests that creating awareness of linkages between improved water service delivery, livelihood and better quality of life for households is more likely to promote the understanding of water as an economic good rather than placing emphasis on marketing water as commodity of which people in study area consider as a free natural gift of nature.

7.10 Institutional arrangement

Policy: Discussions with key informants revealed that there is a signed policy on water and sanitation in the State which covers all LGAs including the study area. However, there are challenges on strategic implementation of the policy. The state policy supports the use of HDW as sustainable means of water supply. There has been a commensurate investment to that regard. The policy did not mention or consider specifically the use of rope pump technology. This may be because of technology being newly introduced to Nigeria as mention in section 5.5.1 and not having gained national recognition yet.

Stakeholders believe there is an opportunity for exploration of self-supply HDW in the area, considering that the State policy clearly states that 'Rural communities will be able to choose from among hand-dug wells where hydrogeology is suitable. And appropriate technologies will consider water quality both at the surface and groundwater' (BSG, 2011).

The concept of using self-supply to meet water demand was not articulated in the policy, the model advocated was the communal model, which this study and previous research has identified as being challenging to operate and maintain. The study found that the idea of accessing safe water from HDW or improving other traditional water methods are unlikely to receive policymakers support because traditional water interventions such as HDW often score poor political points and are perceived as a sub-standard project by communities.

The unit is saddled with the responsibility of providing monitoring, supervision and technical support towards delivering water supply across the local government levels.

The Water and Sanitation Unit of the Local Government, has the following core mandates which include:

- Project supervision and monitoring;
- Establishment of database on water and sanitation facilities and their performance to facilitate community development of water and sanitation committees (WASHCOM);
- Recruitment of community members for training in water facility maintenance;
- Monitoring of progress of LGA Rural Water and Sanitation program;
- Ensuring of provision of water supply and sanitation to the communities;
- Assisting in procurement and technical support at community level.

Discussions reveal that although the WASH unit has been established and functional, as a unit it is still under a department and all the staff were seconded from other departments, so staff still take tasks from their main departments. Upgrading the unit to a department will mean it will have substantive staff and a department head that has the primary responsibility to promote and improve WASH in the LGA. Also, the unit under the purview reports directly to the LGA Chairman or sole administrator as the case maybe. This sets limitations on the capacity of the unit to effectively and independently carry out its function. Hence, its growth or ability to carry out activities is largely depending on the disposition of the sitting Chairman who sets priority projects and programme to funded by the LGA.

Capacity: Staff register and organogram shows that the unit has a staff strength of 29 people. It is practically impossible to effectively oversee over water and sanitation activities in over 350 communities in the area. Its understaffed to effectively oversee water and sanitation service delivery in the area.

Finance: The study found that there was no budget developed annually for the unit, it relied profoundly on external support agencies to carry out its function. One of the key informants was of the opinion that without funding from an external aid agency such as UNICEF, WaterAid, USAID or European Union etc., the unit may cease to exist. Therefore, upgrading the unit to a department will allow it to have the statuary responsibility to produce, seek approval, implement, and monitor budgets like other departments. Instead of relying on donor funds and executive allocation from the LGA, it would work as a department works with a budget approved by the LGA.

7.11 Chapter summary

This chapter has presented discussions and the descriptive analysis of data obtained from fieldwork. Data were gathered from conventional water facility inventory, household survey, water facilities sanitary risk assessments, and water quality tests. The findings informed exploration of options for sustainable water services delivery. Exploring the concept of self-supply, handdug well, rope pump technology as well as a community based water resource management.

Findings strongly suggest a need for technically and financially viable options. In the case of Nigeria huge groundwater resources presents an opportunity to rethink more closely the present use and utilisation of HDW. Where HDW is feasible such as in the study area, a major challenge encountered is on the quality of water gotten from the wells due to the risk of contamination from poor sanitation, unhygienic activities and proximity to latrines.

The results of sanitary risk assessment and water quality tests carried out indicated high risk of contamination from external sources for HDWs which could endanger the overall

groundwater quality in the study area. Therefore, as a safety measure, improving on water lifting device use on the wells, and undertaking sanitary measures aim at minimising faecal contamination would be a major step towards ensuring safe water from the wells. Literature reviews and findings from the field showed that the rope pump presents a locally viable solution in this regard. However, the rope pump technology can only effectively serve limited numbers of users such as a household, group of households in a compound or a very small community, in an ideally self-supply environment.

The study found that although self-supply seems to be feasible, it impacts on local groundwater resources need to be carefully assessed and measures must be taken within the local context to address the potential impact the approach may have on groundwater sources in the area. This will ensure that self-supply HDW with a rope pump can deliver sustainable water services to users over a long time without compromising the ability of future generations to meet their own needs. Therefore, on the premise of the above discussion, exploring the concept community based water resource management towards equitable, efficient, sustainable use and management groundwater sources is important.

Respondent perception was sought on the basic building block of self-supply according to (Sutton, 2007), the viability of the rope pump technology and the adoption of community based water resources management based on the four Dublin principles of water resources management. The analysis, findings and discussion in this chapter form the basis for a proposed a guidance framework that could be adopted by policymakers, practitioners and other stakeholders in the water sector to explore a practicable approach towards achieving sustainable water service delivery in rural communities.

Chapter 8

8.0 Guidance framework development and validation

8.1 Introduction

This chapter presents a proposed Sustainable Rural Water Supply Service Delivery (SRUWASSD) guidance framework. The approach is based on the discussion and findings from the literature reviews, exploratory studies and field investigations. The concept is envisaged to explore the potential in self -supply, using rope pump technology and adopting a Community Based Water Resource Management (CBWRM) approach to support rural water sector practitioners in the planning and implementation of sustainable rural water service supply delivery in Nigeria.

8.2. SRUWASSD guidance framework

The concept emerged from reviewing the failures of community managed water facilities, which leave a sizeable number of facilities non-functional and many people without access to improved water supply across Nigeria. This implies that stakeholders and practitioners in the water sector need to reconsider alternative approaches to water supply service delivery. The guidance framework is centred on the potential that exists in exploring HDW towards meeting communities and households water demand. It is envisaged that it would not only increase household water supply access and coverage but also provide a guide on protecting groundwater resources and how users can operate water facility more sustainably.

Hence, the novelty of this research is the presentation of a Sustainable Rural Water Supply Service Delivery (SRUWASSD) guidance framework and approach. SRUWASSD support the thesis that the obstacle to rural water supply sustainability created by failed community managed water facilities can be reduced through the development of sustainable household options. The framework, also provides an opportunity for practitioners to look beyond service coverage to considering environmental sustainability of water resources by incorporating the concept of community based water resource management in the main stream of rural water supply.

The framework therefore incorporates the concept of HDW self-supply, using rope pump technology for water lifting in a CBWRM approach relating to financial, institutional environmental social and institutional sustainability factors. If implemented, it is considered that it would improve sustainable water services delivery in the study community, and by extension in Nigerian and sub-Sahara Africa.

It is proposed for households and communities with sufficient groundwater that can support perennial use of HDW. It is designed to allow end users and practitioners to apply the guidance on any of the sustainability factor lagging in order to bring out desired sustained water service delivery result. Each of the factors in cooperated into the framework have been discussed individually to allow stakeholders and practitioners to contextualise and adapt to local conditions. Figure 8.1 is an illustration of the overall component of the framework in cooperating all factors considered as well and step by step adaptable implementation guidelines.

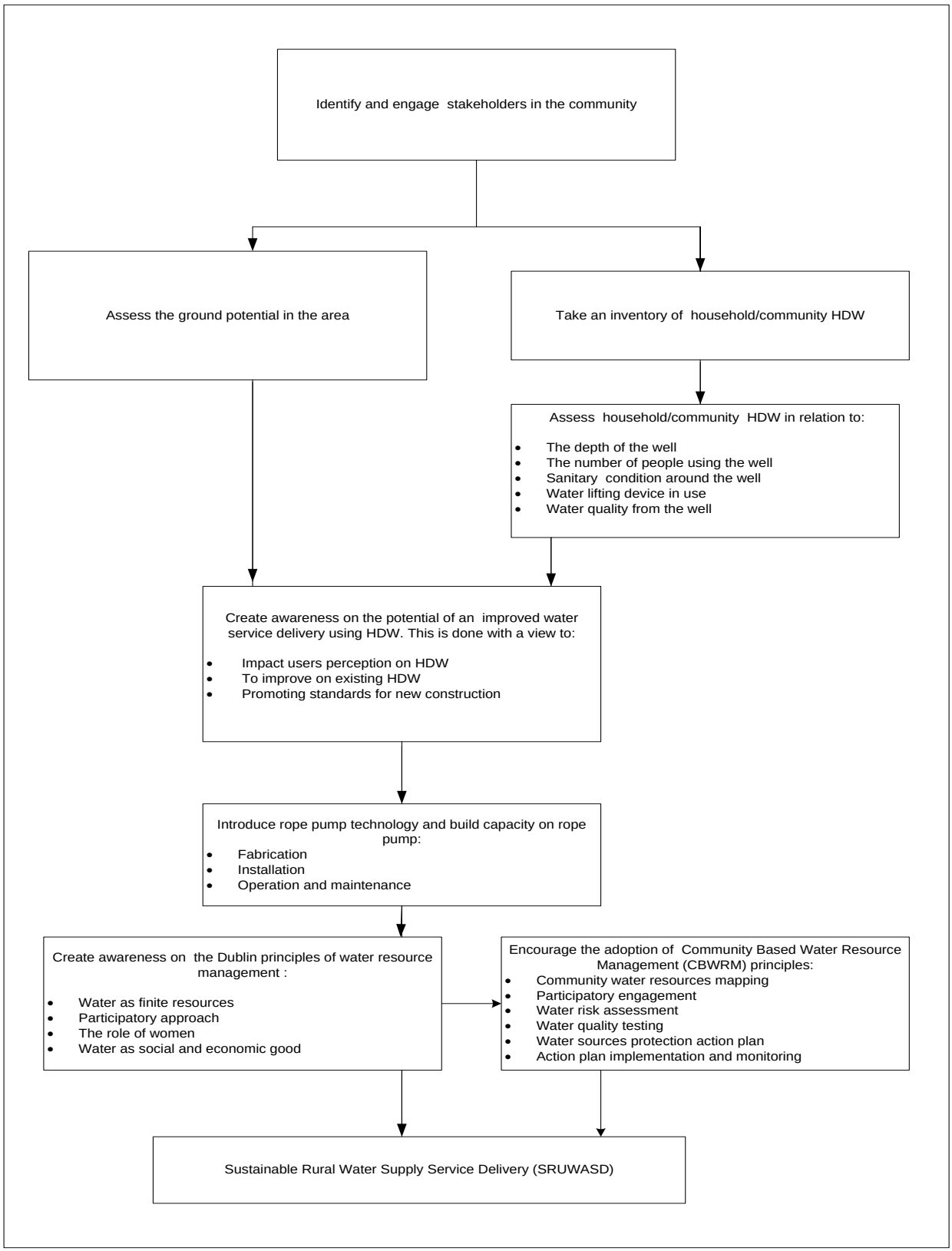


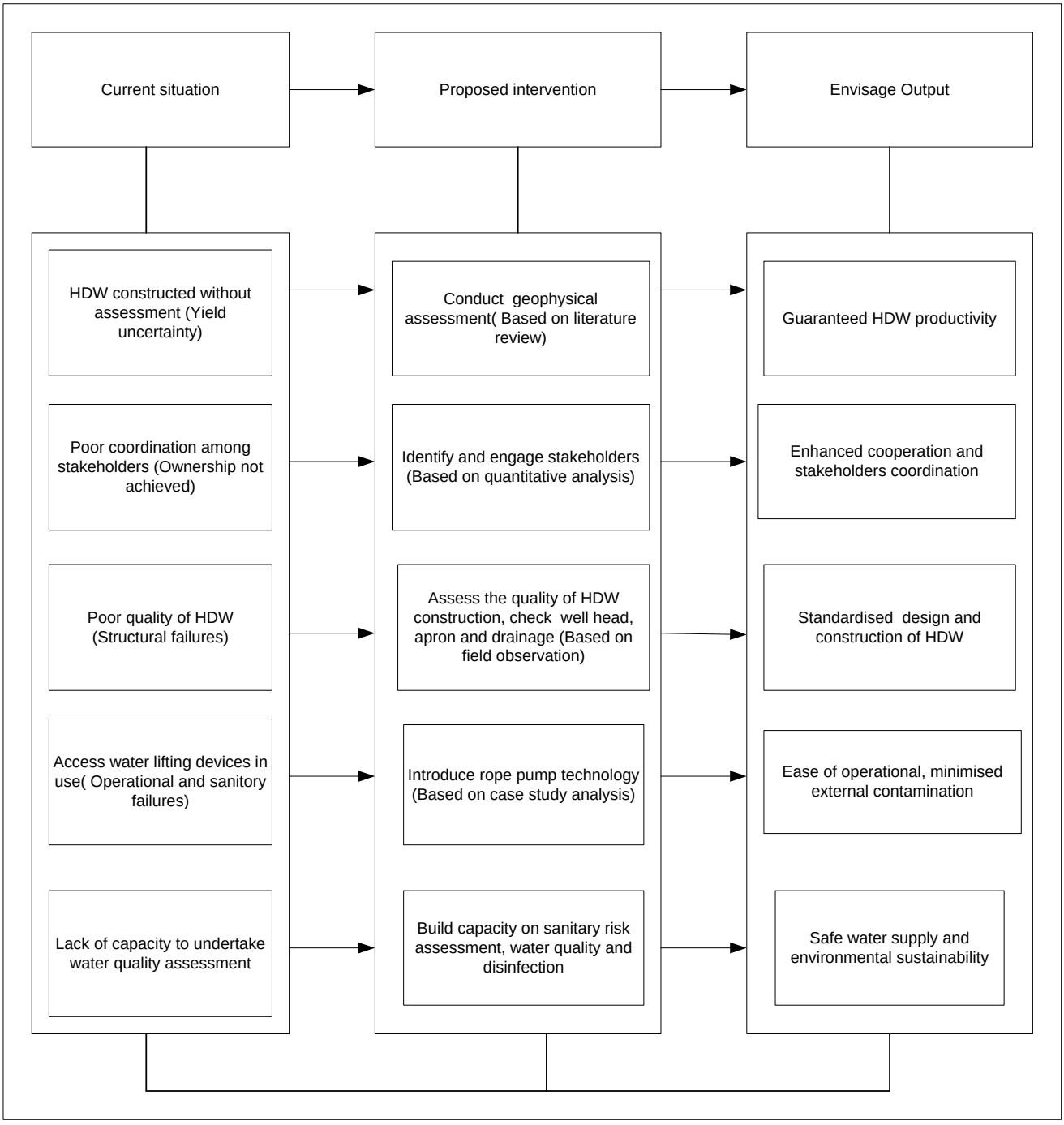
Figure 8.1: SRUWASSD guidance framework.

8.2.1 Technical guidance

Figure 8.2 gives an overview of SRUWASSD framework technical guidance. It contains technical guidance on exploring new and existing HDW, the proposed intervention and envisaged outputs based on the research findings. The procedure outlined below is thus proposed as measures that could impact on the technical capacity of household water facilities to deliver sustainably.

Assess groundwater potential in the community: This should be conducted to determine whether there is sufficient groundwater in an area to support perennial operation of HDW. To achieve this baseline data such as average depth, impact of seasonal weather changes on existing water sources and rate of recharge for existing HDW and other water sources neds to be collected. Other information such as geophysical and hydrological information of the area could be access from local authorities, institutions or private organisations. Assessing viability of HDW in an area help household to weigh the decision to invest in HDW self-supply against benefit that could be derived from year round provision. Figure 8.2 shows the current situation, proposed intervention and envisaged outputs.

Stakeholder engagement: Engage with community stakeholders and local institutions to assess the quality of existing HDW construction. This should involve detailed assessment of HDW basic components such as the well-head, the well-shaft and the well-intake structure. Attention should be given to the HDW external structures such as the height of well-head, apron and drainage channels. Where these external superstructures are observed to be poorly constructed, damaged or not available, they should be repaired, renovated or newly constructed.



Figures 8.2. The proposed SRUWASSD technical guidance

Assess existing water lifting device: For an existing well, assess the water lifting device presently in use. Where bucket and line is in use, rope pump technology should be considered. Findings from this research showed that the prevalent use of line and bucket is one of the most important factors in HDW contamination. Since many wells used in by household and communities experience multiple usages of line and bucket on a single well; introducing the RPT could impact on blocking of faecal-oral transmission routes into the water point.

Facilitate standardisation of HDW design and construction: Local and state agencies in collaboration with relevant stakeholders should develop a standardised HDW design and construction procedures. Encourage household adoption of a standardised HDW design. The design should incorporate minimum requirements and materials for HDW construction. The construction should aim at preventing wastewater infiltration and flood water from entering the Well. The households should be encouraged to locate the HDW at least 20m uphill from a pit latrine in accordance with the WHO guidance framework. Also, latrine constructors should be encouraged to construct a pit less than 3m deep and where possible the pit wall should be lined. This prevent infiltration and/or leaching into groundwater sources as well as increasing bacteria travel time from the point of contamination.

Build stakeholder capacity: Build the capacity of the water and sanitations units, private sector service providers, households and community members, to enable them to carry out sanitary risk inspection, water quality testing, and water point disinfection. The ability of stakeholders to effectively carry out simple water quality test should be considered. Water quality test such as hydrogen sulphide (H_2S) paper-strip tests to indicate contamination in

drinking water for monitoring water quality in local communities without having to depend on laboratory-based water quality testing should be explored. This capacity will help households to identify if there is contamination as well as sources of contamination and allow physical and chemical treatment where necessary.

8.2.2 Social guidance

The social guidance framework focuses on the issues of water supply needs, stakeholder demographics, institutions and women amongst others. The guidance below is recommended as a result of findings of this study.

Assess household water supply need: A knowledge of water as a finite resource, hydrology, population and climate change and its impact on local water resources was found to impact attitudes to sustainable water resources management. A better understanding of water sources and resources in the communities thus affects user perspectives and disposition to managing the resources.

Undertake community stakeholder mapping: In many rural communities in Nigeria, rural areas introducing new a concept or modifying an old approach requires the support of key influential groups and community members. Result in section 7.3.3 suggest that traditional and religious institutions may have considerable influence on the success or failure of development projects and activities in the area. It is thus proposed that these groups are properly engaged with the development.

Raise stakeholder awareness: There should be raised stakeholder awareness on the linkages between improved and safe water supply, health and the environmental. The could be an impediment to unsustainable services has been the lack of sufficient awareness among users. The awareness strategy should adapt to local cultures and should be delivered in local languages. The most suitable media of outreach should be exploited. Section 7.4.5 Radio broadcasting and communication through religious centres were found to be the most reliable media in reaching households and communities in the area.

Facilitate stakeholder interaction: Encourage community-based institutions such as women groups, youth groups, Community Development Associations, traditional councils, Water and Sanitation Committees (WASHCOMs) and other identified interest groups to establish continuous interaction with local authorities, state and federal water policy implementing agencies. This would aid identification of creative and innovative processes at a local level that can support sustainable water service delivery on a wider scale. It is envisaged that this will ensure continuous development and improvement in the system.

Encourage women participation: Encourage the increased participation of women in the planning, and implementation of water service delivery. This study found that women play fewer roles than men in making key water service delivery decisions in households or communities (see section 3.3.8) . Recognising that women have important roles in the day-to-day management and running of water facilities as well as expanding their sphere of influence would positively impact on sustainable delivery

8.2.3 Financial guidance

Figure 8.3 shows a diagrammatic representation of SRUWASSD financial guidance proposed for improved rural water service delivery. The guidance emerged from the findings in literatures that technical and financial issues are the primary impediments to sustainable rural water service delivery particularly for community based or managed water facilities. It is founded on respondent views on capacity to finance construction, operation and maintenance of water services.

The concept relies on individual or community investment to improve their water supply access. It is aimed at enabling sustainable water service delivery using minimum initial capital as well as running costs. Exploring this framework is envisaged to benefit millions presently using line and bucket and other less hygienic water lifting devices of Nigerians and sub-Saharan Africa. It should. This with a view that present unimproved HDW users will only require capital costs for rehabilitation, renovation or repairs of an existing wells.

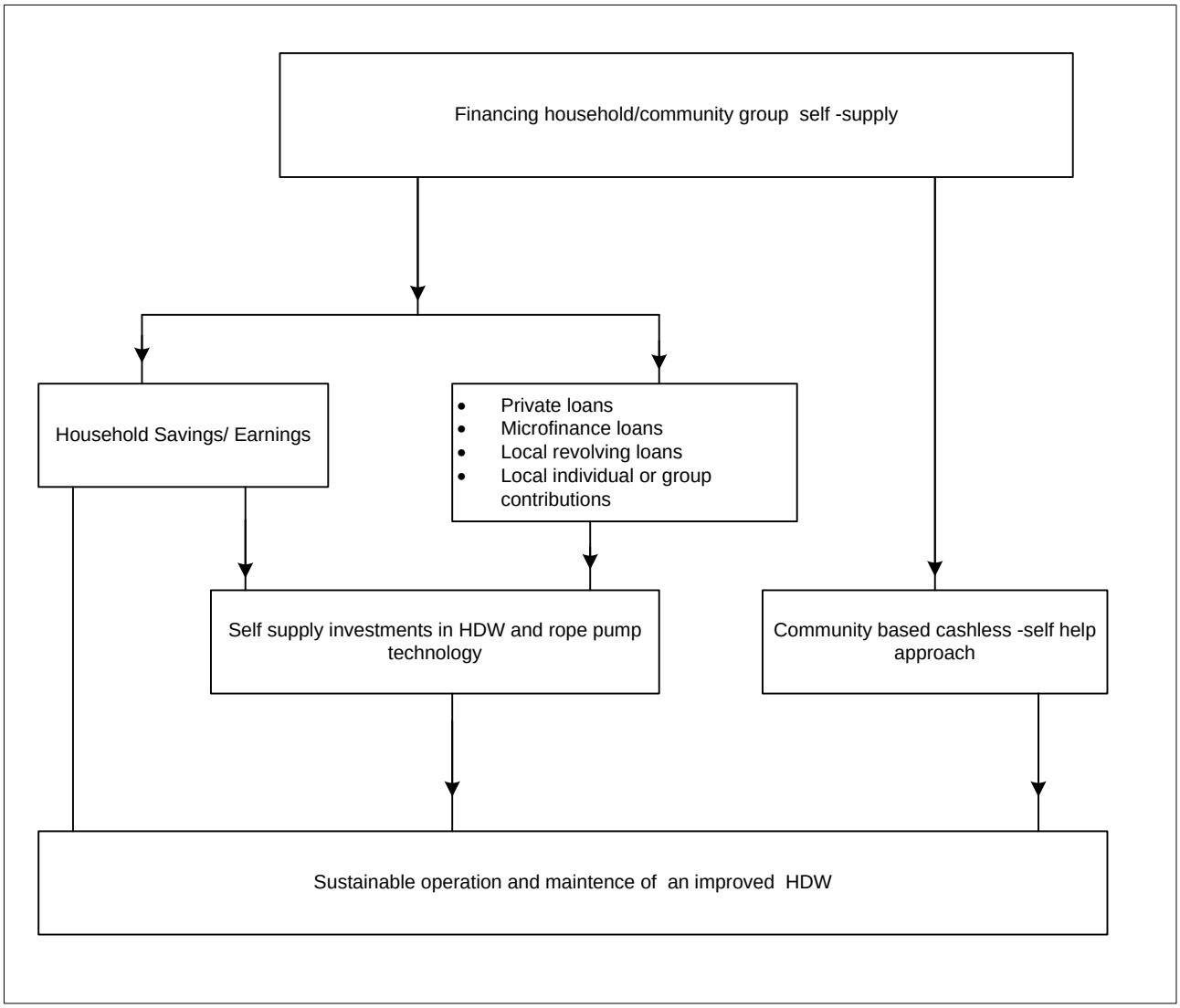


Figure 8.3 Financial SRUWASSD Guidance Framework

Encourage household financing of self-supply water facilities: Encourage households to prioritize improving their water source facilities without depending on subsidy or external support through personal savings. This study found that aside household personal savings, people in the community engage in an interest free rotatory contribution savings schemes amongst community members. This a system where a group of people come together to put certain agreed amounts aside in a common purse either daily, weekly or monthly as the case maybe, for a personal use on a rotating basis. This can be an

interest free lump sum, which individual can leverage for their own investment in improved household access to water supply.

Facilitate households to access loans: The study found that the majority of households used their savings to construct their self-supplied water facility. However, it is envisaged that that improved access to low-interest loans would empower households and improve their economic standing, thereby enabling household to invest in improved water service delivery.

Explore communal support: There is a need to explore community-based mutual support amongst households. This is an approach in many local communities in Nigeria, where there is an informal agreement in which people come together to support each other in solidarity to meet a need such as building a house or cultivating farmland and so on. This is done in turn for every member of the participating team to have their own projects completed. This model should be encouraged to minimise the initial cost of investment in self-supply water facilities.

8.2.4 Environmental guidance

A sustainable water service delivery is that which minimises the risk of potential harm to the environment and poses no significant public health hazards. Facilities such as pit latrines, community dump sites and drainage channels directly observed during field investigation pose significant risks to groundwater contamination in the study area. Environmental guidance is hereby proposed to ensure that water service delivery is operationally and environmentally viable.

The proposed environmental guidance framework was hinged on the CBWRM approach. Figure 8.4 describes the proposed guidance towards water source protection highlighted as follows:

- Engage households and communities in participatory approach;
- Facilitate and create awareness on basic hydrological cycle, global water resources, population growth and climate change;
- Facilitate a ‘’;/of awareness on Dublin principle of water resource management;
- Facilitate and encourage the adoption of community based water resource management;
- Build capacity of households and community water users on:
    - Water resource mapping
    - Water safety and risk assessment
    - Water quality testing
    - HDW disinfection

- Facilitate the development of community based water resource management action plan to include implementation, monitoring and evaluation. Households and/or community members should be encouraged to develop their own CBWRM action plan. This should include possible documentation of changes in water levels, seasonal variation, and changes in water demand as well as establish a routine monitoring, evaluation and feedback mechanism.

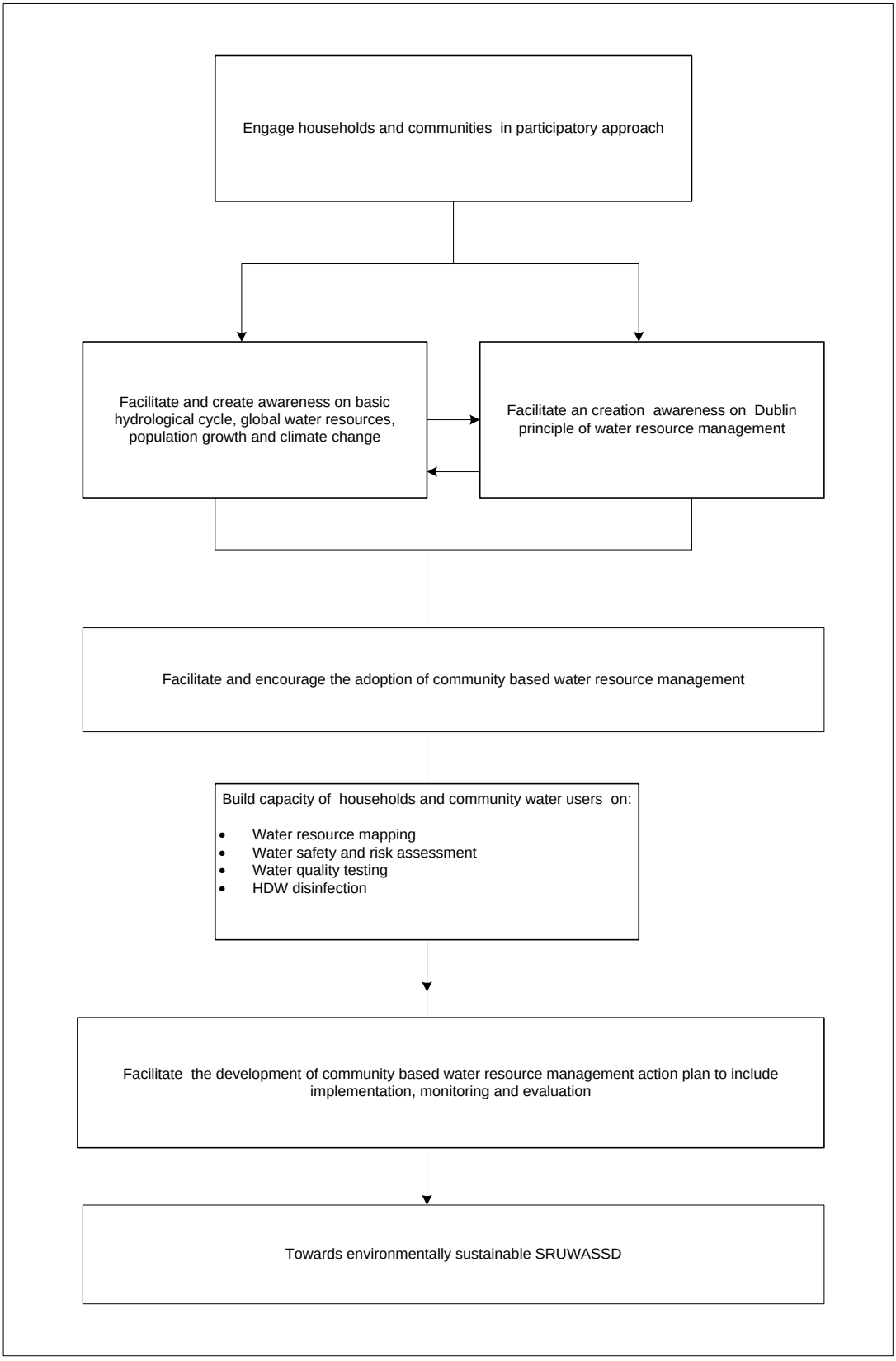


Figure 8.4: Proposed guidance framework for environmental sustainability

8.2.5 Institutional guidance

Institutional guidance framework for water service delivery consists of a wide range of policies and organisations that should be in place to develop and manage water supply and water resources at different levels of a society. Implementing an institutional framework is an important process for preparation for sustainable water service delivery. The proposed SRUWASSD institutional guidance therefore incorporates factors relating to capacity, interaction, and policy implementation outlined as follows:

Strengthen the capacity of water and sanitation units: There is a need to invest in the capacity of the water and sanitation unit and other related agencies in in the study area in order for them to effectively carry out their functions. This will enable the unit towards achieving an improved HDW delivery.

The capacity to effectively mobilise and sensitise household and communities could also encourage the uptake of HDW as a viable water source through the provision of guidance on HDW construction, water quality testing and disinfection as well as CBWRM. Also, upgrading water and sanitation units into full fledge department will impact on its access to budgetary allocation, ability to recruit and retain staff and enhance capacity in policy development and implementation in the study area.

Facilitate stakeholder interaction and feedback mechanism platform: Local, State, Federal and community based institutions should interact regularly and provide feedback on policy and operational issues. This will improve coordination of water services delivery, resources allocation and ensure synergy in the system. It will also create a platform to evaluate how services can be better delivered.

Prioritise the use of HDW and develop clear implementation guidelines for self-supply: There is need to revisit and prioritise the development and use of HDW in Nigeria. In addition, clear guidelines should be laid out for the development and sustainability of HDW. This should give impetus to safe use of HDW in households and communities. This study found that the state policy recognised the use of HDW as a veritable water source. However, HDW have not been given the kind of priority required to maximise the potential benefit that could be derived.

8.3 Feedback on proposed guidance framework

The results and findings discussed in chapter 7 form the basis for the development of Sustainable Rural Water Service Delivery (SRUWASSD) guidance framework presented in this chapter. The views of 14 sector practitioners and experts were sought regarding the applicability and relevance of guidance framework toward enhancing sustainable water supply in the study area.

Each respondent was asked to rate the relevance of the guidance framework based on five sustainability drivers identified in literature. The respondents score the guidance. between 1 and 5 responses on a scale representing lowest to highest relevance. The overall response is presented in Table 8.1 The Table shows the designation of stakeholders and professionals in the rural water supply sector.

Table 8.1 stakeholders feedback on proposed guidance framework n =14

S/No	Stakeholders	*Financial*	*Institutional*	*Environmental*	*Social*	*Technical*	*Overall guidance rating*
1	Water consultant	4	3	4	3	5	76%
2	Programme Officer	3	4	3	5	4	76%
3	WASH Unit coordinator	4	3	3	3	4	68%
5	HDW owners	5	3	3	2	4	68%
6	HDW water user	5	3	4	3	5	80%
7	Senior technical Officer - RUWASSA	3	4	3	2	4	64%
7	Academic researcher	3	3	4	3	5	72%
8	Community mobilisation officer	4	4	3	3	5	76%
9	State ministry of health	3	3	4	2	4	64%
10	Traditional council member	4	4	4	4	5	84%
11	Private sector practitioner	3	4	4	2	4	68%
12	Local artisans	4	3	3	3	5	72%
13	Community women leader	4	2	4	3	5	72%
14	WASH Expert (External support Agency)	4	3	4	3	5	76%
	Individual Factor rating	74%	65%	73%	59%	90%	

From the survey conducted and the responses obtained, the 14 stakeholders indicated an overall relevance rating of between 64-84%. On the individual sustainability factors rating, Technical factor had a 90%, Financial 74%, Environmental 73%, Institutional 65% and Social 59%. Thus, both individual and overall sustainability factor rating indicated that

framework can be considered relevant toward achieving sustainable water service delivery.

8.4 Relevance of the guidance framework

The proposed SRUWASSD framework has an average individual rating of 73% on the relevance and applicability of the proposed framework. A summary of the responses to the questions in the shows that most respondents agreed that the guidance framework would be applicable to addressing the problem of sustainable rural water supply in the study area. This study that the guidance framework can be considered as a suitable approach toward improving sustained rural water service delivery. This suggests that the guidance framework represents a constructive contribution to the body of knowledge and practise of sustainability rural water supply in developing countries.

Figure 8.5 depicts stakeholders rating on the relevance of the proposed SRUWASSD framework on each of the sustainability factors considered. Its suggest that the framework could have 90% technical relevance, 74% financial relevance and 73% environmentally relevance. The pentagon shape diagram use illustrates the equality of each of the sustainability driver for a given system to function optimally and sustainably. Thus, a sustainable facility could be said to be one in which well balance integration of the all sustainability drivers co-exist

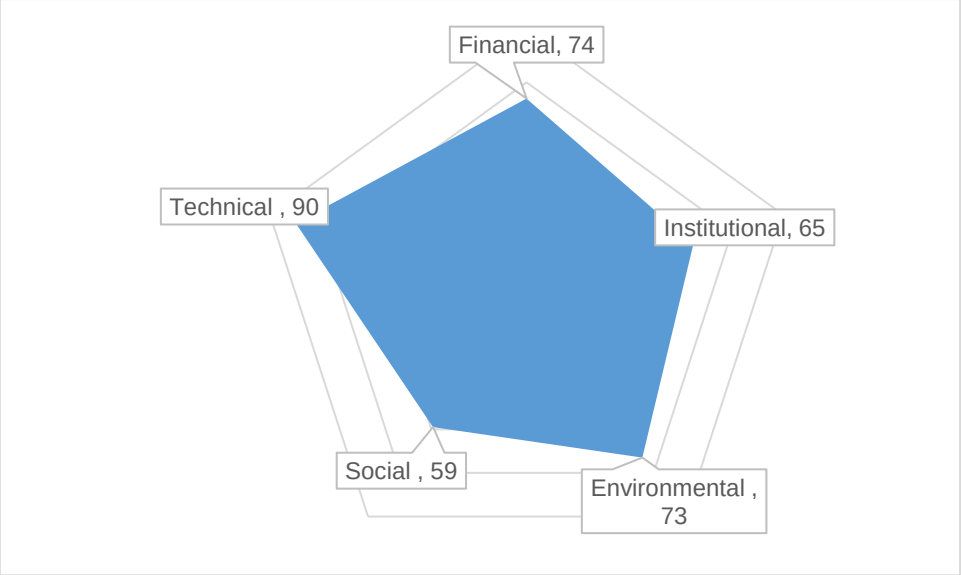


Figure 8.5: Proposed guidance framework relevance rating

The guidance framework can be recommended to stakeholders in the water supply subsector subject to future modifications, research and local context that can improve its acceptability and applicability.

8.5 Constructive criticisms of the proposed guidance framework

Although the framework received high relevance ratings, some concerns were raised and recommendations made that can facilitate the application of the framework in a wider context as follows.

- Concerns were raised on the limitation of the approach in areas where HDW may be subject to seasonal change in ground water level
- The limited capacity and availability of organised private sector for standardised HDW construction and rope pump fabricating in the study area.
- The success of the approach can be subjective due to differences in the social and demographic structure of various rural communities in Nigeria.
- Although individuals can take the decision to have self -supply, however, implementing the Community-Based Water Resource Management requires the interest and cooperation of other members of the family.

- The skill required to carry out water tests, sanitary risk assessments and disinfection could become a serious challenge to households.
- The capacity of the local institution to successfully facilitate the awareness and implementation of the framework entire study area town is limited due to resource constrained.

8.6 Chapter summary

This chapter presented the proposed Sustainable Rural Water Supply Service Delivery (SRUWASSD) guidance framework. The guidance framework is proposed for communities with sufficient groundwater that can support a perennial use of HDW. The framework provides guidance for each sustainability factor identified in the literature. The framework is designed to allow end users and practitioners to apply the guidance on any of the sustainability factor lacking, to achieve desired sustained water service delivery.

SRUWASSD is underpinned by the principle that HDW can be utilised to increase access to improved water supply to household who will normally be affected by breakdown in community managed water facilities, the time and effort required to collect outside their homes. It also, presented the rope pump as a viable alternative technical option that can be operated and maintained by individual household. The rope pump option improves water safety for traditional HDW by cutting off some contamination route into the well such as from line buckets.

The guidance framework put forward a unique water service sustainability concept in the sense that previous approaches focused more on operational sustainability with little or no attention on the environment, particularly ground water resources but the SRUWASSD model in a broad context provides for the protection of groundwater by incorporating

CBWRM approach. This is envisaging to engender technical, financial and environmental sustainability in rural water service delivery.

The proposed framework was rated by 14 stakeholders from across the water sector ranging from community members, water professionals and public officials. These stakeholders rated the relevance and suitability of the proposed framework as well as its applicability in the Nigerian rural water supply context. The guidance framework was rated of high relevance, suitable and applicable. Some recommendations were also made to ensure that future work will incorporate consideration of wider applicability.

Chapter 9

9.0 Research recommendations and conclusion

9.1 Introduction

This chapter concludes the thesis by recapping the crucial points that have emerged from this research. It demonstrates that the research to very large extent successfully addressed the research questions, aim and objectives. It also highlights the research contribution to knowledge, the study limitation as well as proposed recommendations for future work.

9.2 Overview of research

The study developed from a fundamental understanding of water resources and water supply development at the global, regional and national level gained through a thorough review of the sustainable water service delivery concept. It discussed various sustainable water service delivery frameworks and identified core sustainability drivers. The sustainability drivers are financial, institutional, environmental, social and technical factors. However, amongst the drivers, it was established from literature that the fundamental challenge to rural water facility sustainability are technical and financial issues.

The technical component relates to skills, expertise and material, and complexity of the system used for water supply and the financial component relates to initial cost of construction, operation and maintenance. In addition, however the environment aspect of water service delivery was also found to have been relegated to the background, and has

received little or no attention from professional, policy makers and users in the water sector over the years.

The review of the Nigerian water supply sector clearly showed that, although there has been increase in service coverage in the country over the last twenty years, majority of the improved access to water supply was through ground water sources. This further strengthen the need to reconsider environmental sustainability of the groundwater sources. Also, the study found an average breakdown rate of about 40% in water facilities. Reasons for the failure include, poor sense of ownership particularly for community managed water sources, technical complexity of the system in use and the financial resources require to manage and operate the facilities.

This situation has raised the questions of whether household owned and managed water facilities can reduce the overall burden of non-functionality in developing countries. Also, there is an overarching failure to recognised the delicate role of the environment in ensuring sustainable access to domestic water supply in Nigeria. This development informed the research focus to explore alternative options that could resolve some of these challenges. The decision therefore was to explore the traditional option of self-supply HDW with mounted rope pump technology which was found to be viable, particularly in areas that can support perennial use of HDW. But a major drawback of this option is that it tends to be more appropriate for individual or group of communal households rather a servicing a whole community, particularly areas with large population.

However, if every individual household in a community used self-supply HDW this might impact on the overall quality of ground water. Hence, a need to develop a guidance

framework that could support the development of self-supply HDW using rope pump technology as well as efficient exploitation of ground water resources to meet water demands leading to the development of Sustainable Rural Water Supply Service Delivery Concept (SRUWASSD).

9.3 Achieving the research objectives

9.3.1 Conduct a review of global drinking water development, trends and coverage

The objective to review the global drinking water trends and coverage was achieved in chapter 2 of the thesis. The chapter discussed global water resource and drinking water coverage. It highlighted the importance of improved access to safe drinking water to health, general wellbeing and in human development. It also highlighted notable past and a recent milestone in global engagement towards attaining universal water services coverage. It highlighted challenges to increasing drinking water coverage as well as ensuring services are sustainable.

It also discussed fundamental challenges in the water sector as well the importance and benefit of improved access to water supply to human development. It further established the fact that the absence of water facilities constitutes a major impediment to health, welfare and human development. The chapter also established the need for an inquiry into sustainable services due to present level of water facilities failure in developing countries, particularly in sub-Sahara Africa, citing examples across the region.

9.3.2 Critically review sustainable water service delivery concepts

This chapter presented the general idea of sustainability and sustainable development concept in relation to sustainable water service delivery. Several sustainable water services delivery concepts reviewed can broadly categorised into proponent of continuous external support post implementation and the those advocating little or no external support after an intervention in a community. The idea of providing continuous support to communities and users may not be feasible due to limited human, material and financial resources available to local authorities. Priority is more likely to be given to expanding services coverage to unserved populations rather than expending resources on following up serviced communities.

It was also clear from the literature that expanding inquiry beyond simply the building of water facilities and assessing what is or, in many cases, what is not working around these water facilities is necessary. Three main service delivery approaches were noted as; Externally driven approach, Enterprise driven - private sector approach, and Self-supply initiatives. Also, five core drivers of sustainability were identified as financial, institutional, environmental social and technical factors. The research explored these drivers as pointers with a view to develop for an alternative solution that is manageable at household levels.

9.3.3 Undertake review of the current state of rural water service delivery in Nigeria

The objective to review the current state of water service delivery in Nigeria was achieved in chapter 3. This chapter presented a general overview of the Nigerian state, discussed high population growth rate, amount of water resources potential, challenges and cost

implications of meeting drinking water demand in Nigeria. The chapter revealed that over five decades of water sector development such as the creation of institutional structures, roles and responsibilities and policies, have not translated into universal coverage in water supply in the country.

Drinking water trend and coverage were critically reviewed, highlighting key institutional development roles and responsibilities in the water sector. It also highlighted water and other related policies that have evolved over time. The chapter also established that there are challenges to sustainable water delivery in Nigeria as well as huge service coverage gap in the country. It was found that beyond the lack of facilities is a greater task of operating and maintain existing facilities sustainably.

The trends and coverage presented in this chapter established that between 1990 and 2015 there is an overall increase in access in rural, small town and urban drinking water supply in Nigeria. However, the increase in improved access to water supply in Nigeria and many other Sub-Sahara Africa countries is highly dependent on exploitation of groundwater resources. It was clear that groundwater is the most accessed water source indicating failure of utilities to cope with municipal water demand in the country. But more worrisome is the fact that many facilities provided are longer non-functioning as stated in coverage report and the sustainability of water sources was not given priority raising the question of how sustainable are the water facilities and the water sources in Nigeria. For the rural water facilities, it was found that the service delivery and approach, technology and the cost of operation and maintenance are the main factors responsible for the lack of sustainability. This formed form the underlying concept for the subsequent exploratory studies for a more sustainable approach.

9.3.4 Conduct an exploratory study on sustainable water service delivery

The objective to conduct detailed exploratory study on sustainable water service delivery principally to find alternative solutions was achieved in chapter 5. Technical options considered include HDW, rope pump technology, self-supply options and community based water resource management opportunities towards sustainability. The exploration also led to a need to focus more closely on the environment. The chapter discussed the building blocks of self -supply, HDW, viability of the rope pump technology, community based water resource management and the applicability of Dublin principle towards sustainable water service delivery.

9.3.5 Establish an appropriate research methodology, fieldwork and data tools

The objective to establish an appropriate research methodology, for fieldwork, data gathering tools and analytical techniques was achieved in chapter 6. Chapter 6 informed the insight into the kind of data to be collected, to identify the most appropriate methodology, the chapter presented a review of the various methodologies and identified the most suitable approach as mixed method.

Data were obtained by mixed method approach comparing water facility inventory survey, household survey, interviews, sanitary risk assessment, water quality test, field observations and perception surveys and informal discussions. The chapter presented how the research was designed, and data was obtained and analysed as appropriate to address the research question, aims and objectives. Result for analysis were presented fully and discussed in chapter 7

9.3.6 Analyse the field data gathered

The objective to Analyse the field data gathered to gain insight into the current challenges and opportunities to aid development of a sustainable water service delivery guideline framework was achieved in chapter 8. This chapter presented the proposed Sustainable Rural Water Supply Service Delivery (SRUWASSD) guidance framework. The guidance framework is proposed for communities with groundwater reserves that are sufficient to support a perennial use of HDW. The framework is designed to allow professionals, policymakers and other practitioners to apply the guidance on any of the sustainability drivers deficient based on context to achieve sustained service delivery. Also, the framework proposes a unique beyond just achieving functional operation and maintenance of water facilities by incorporating and focusing also on environmental sustainability of water services delivery.

9.3.7 Validate the technical effectiveness and usefulness of the guidance framework

The objective to validate the technical effectiveness and usefulness of the guidance framework from stakeholder's perspectives was achieved in chapter 8. The proposed SRUWASSD guidance was based on the findings derived from literature and field investigation. The framework was validated seeking stakeholder perspective and perception on relevance and applicability of guidance using survey evaluation process involving 14 key stakeholders from across the water sector including community members, water professionals and public officials.

These stakeholders rated its applicability in the Nigerian rural water supply water context. It was rated as having relevance, suitability and applicable. Some recommendations were also made to ensure that future work will incorporate consideration for wider scale-up.

9.4 Contribution to knowledge

This section presents the significant contribution to the body of knowledge as outlined below:

- The research has established that there has been concerted effort in water resource development and drive towards increasing drinking water coverage globally, particularly in the developed countries. However, concerns over sustainable water resources and water service delivery remain a daunting challenge in the water sector. For example, in the study area about 40% overall water facility non-functionality was recorded area and a considerable number of HDW tested have biological contamination above standard NSDWQ and WHO thresholds.

- Previous studies have focused on the sustainability of water service delivery based on a community management model. However, this study is one of the very few research that shift the focus from community to individual and household water facility initiative, ownership and responsibility, aimed at delivering sustainable service.

- The research has established that rope pump technology could have enormous potential in sustainable water services delivery in the study area. Millions of Nigerians presently using line and bucket, thus stand to benefit from the advantages the technology could offer.

- The research established that the availability of technical option, access to finance, presence and engagement of private sector service providers are essential building block of self-supply (Sutton, 2007). However, enhanced policy environment may have little or no impact on the decision of HDW owners in the study area to construct their facilities, rather poor

public water facility, population growth and personal convenient were found to be the motivating factors. Therefore, rather than constituting a barrier to self-supply, the poor policy environment has engendered widespread unregulated practice in the study area.

- Perceptions survey from respondents also suggests that creating an awareness of comparative advantage and linkages between improved water service delivery, livelihood and better quality of life for household is more likely to promote the understanding of water as an economic good rather than placing emphasis on social marketing of water as commodity of which many in study area consider as a free natural gift of nature.

- This research successfully presented a SRUWASSD approach. It is a concept that goes beyond addressing the technical and financial sustainability challenge in water service provision, but also provides an appropriate guide towards environmental sustainability particularly as it relates with groundwater exploration and exploitation. The SRUWASSD approach presented a range of guidance that could be adopted for each of the five drivers of sustainability identified to local context by household and communities towards sustainable water service delivery.

- The research clearly presented SRUWASSD implementation guidance which linked rural sustainable water service delivery and environmental sustainability using self-supply HDW approach, the use of rope pump technology in conjunction with community-based water resources management at household level hitherto relegated to the background. Therefore, the study has uniquely mainstreamed groundwater protection as a vital aspect of water service delivery and environmental sustainability.

9.5. Research limitations

- This study is limited to water service delivery in the study area. However, some of the research findings are likely to be applicable to many communities where similar technical and environmental conditions support the use of HDW.

- The literacy level in the study area in some cases necessitated the questionnaire to be interpreted in the local language (Hausa), this could have resulted in the loss in the meaning of the question due to lack of appropriate expressions.

- The sample size of this study may be relatively small in the context of Nigeria as a whole or even in Bauchi state where the data were collected.

- The data gathering tools, scoring and indicators may have strongly or weakly reflected some of the sustainability criteria.

9.6 Recommendation

9.6.1 Policy recommendations

- The failure of community managed water facilities is driving households and communities to consider self-supply HDW. The demand for groundwater is becoming higher in Nigeria due high population growth and dwindling resources. This situation has led to unregulated groundwater exploration and exploitation. The practice needs to be regulated through policy development, legislation and enforcement of water resource management laws as careful management is required to avoid degradation of groundwater quality

- The Local, State and Federal government in Nigeria need to collaborate with stakeholders in the areas of ground water exploitation. There is need to adopt an SRUWASSD - community Based Water Resource Management approach to ensure water supply projects do not have an adverse environmental impact on groundwater resources through increased wastewater discharge and poor sanitation around the water so as to avert any groundwater contamination and pollution originating from self-supply rural water supply.

- In the implementation of the SRUWASSD approach there is need to build effective community participation. The approach requires the involvement and collaboration of a wide range of stakeholders listed in Section 2.5 and Section 7.3.3 in the study area. This is vital for enhancing implementation, acceptance and use of HDW as well as ensuring ownership and sustainability. The study suggests that the opportunity to explore HDW to improve increased water service sustainability and coverage, could however have environmental impact. Therefore, effort must be made to ensure that exploiting ground water resources to meet present water needs does not jeopardise the ability of future generation to meet their own water needs.

9.6.2 Recommendation for further research

This study has explored opportunities that exist for sustainable water service deliver in rural and remote communities in Nigeria. The findings of the study have significantly contributed to the body of knowledge in the sector.

- Further studies should be undertaken to better understand how private sector participation can be effective in rural areas where demand for services may be limited, in order to promote effective partnerships with communities, households and other service users.

- Further studies should be undertaken on the cost of operation and maintenance using the proposed approach as well as identify effective financial mechanisms that engender investment in sustainable self-supply.

- Further studies can be undertaken to explore how the role of women in different social, cultural and geopolitical settings impact on the adoption of the proposed SRUWASSD approach.

- The cost implication of implementing SRUWASSD approach is outside the scope of this research. Further research is therefore advised to address the cost of the approach towards sustainable water service delivery.

- Research should be undertaken to better understand how an improved policy environment can impact on the applicability of the proposed SRUWASSD guidance framework in rural communities in Nigeria.

9.7 Research conclusion

This research has shown that there is a potential for sustainable rural water supply service delivery through self-supply HDW, using simple technology like the rope pump and engaging the concept of community based water resources management approach towards

ground water protection. This approach should address, technical, financial and environmental aspect of water service delivery. The thesis also supports the view that failures of community managed water facilities in many developing countries could be minimised through exploring a household approach. The SRUWASSD guidance framework proposed in this research provide a practicable tool for stakeholders, practitioners and policymaker in decision making towards achievable sustainable water service delivery in Nigeria.

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Appendices: A

Dear Sir,

Invitation to participate in research interviews

"My name is Dayo Olugboye, I am a research student at the University of Wolverhampton undertaking a Ph.D. research on Sustainable Rural Water Service Delivery. I would like to invite you to participate in an interview, as part of the research, which aims to explore options for sustainable water service delivery in Nigeria. The information provided will help understand the situation in your community.

I would like to ask you to participate by answering questions that can help my understanding. There is no right or wrong answer. If there are any questions that you do not want to answer, you can choose not to answer them. The interview takes not more than 30 minutes.
All information you provide will be kept safe, and only used for a summary report where nobody will get to know the answer you gave"

Yours sincerely,

Dayo Olugboye

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Appendices: B

Water facility inventory survey

Type of facility …….
Facility code……
Date…….
Location: Latitude …… Longitude……

Facility	Functional	Partially function	Non-functional
Handpump boreholes			
Protected well			
Motorised borehole			
Solar powered borehole			
Others			

Inventory guidance Note:

- Functional: Delivering water normally and reasonable user expectation
- Partially functional: Delivering water despite some technical challenges – requiring servicing or repairs
- Non-functional: Broken down and has ceased functioning

Appendices: C

HDW WATER QUALITY SANITARY INSPECTION FORM

I. General Information

a) Village: ----------

b) W code: ----------

c) Community: ----------

d) Local Government Area: ----------

e) Date and time of visit: ----------

f) State: ----------

II. Specific diagnostic information for assessment

Risk

1. Is there a latrine within 10m of the well? Y/N
2. Is the nearest latrine uphill of the well? Y/N
3. Is there any other source of pollution within 10m of the well? (E.g. animal breeding, cultivation, road construction and industries) Y/N
4. Is the drainage faulty allowing pounding within 3m of the well? Y/N
5. Is the drainage channel cracked, broken or need of cleaning? Y/N
6. Is the cement floor less than 2m in diameter around the top of the well? Y/N
7. Does spilt water collects in the apron are? Y/N
8. Are there cracks on the cement floor? Y/N
9. Is the lifting system loose or not working properly? Y/N
10. Is the well cover slab cracked and unsanitary? Y/N

Total Score of Risk --------- /10

III Result and Comments

a. Risk score (Tick appropriate)

(0-2 =low, 3-5= medium, 6-8= high, 9-10=very high)

c. The following important points of risk were noted: (list nos. 1-10).

d. Additional comment (continue on the back of the form if necessary).

Name of inspector signature and date) _____

Source: (WHO, 1997)

Appendices: D

Household Questionnaire

Community Profile

1. **State: ----------**
2. **LGA: ----------**
3. **Community: ----------**

Household Characteristic

4. **Status of Occupation**
   1. Owner 2. Co-owner 3. Tenant
5. **Marital status**
   1. Married 2. Single 3. Divorced 4. Widowed

6. **If married, what type of marriage?**
   1. Polygamous 2. Monogamous

7. **If polygamous, how many wives?**
   1. Two 2. Three 3. Four 4. More than Four

8. **Position of respondent within the household**
   1. Husband 2. Wife 3. Adult Member of household

9. **What is the highest educational level attained by anyone in the household?**
   1. Primary 2. Secondary 3. Higher 4. Islamic education 5. None

10. **Occupation of household head**

    1. Unemployed 2. Student

    3. Housewife 4. Retired/Pensioner

    5. Farmer 6. Merchant/Trader

    7. Self-employed 8. Artisan

    9. Civil Servant

11. **How would you classify the economic situation of your Household?**

    1. Very Poor 2. Poor 3. Rich

12. **What are the channels/methods of information dissemination in this community?**

1. Radio
2. Newspapers
3. Television
4. Posters
5. Religious centre
6. Schools
7. Clinics
8. Traditional ruler
9. Telephone/Gsm
10. Others (specify_____)

13. What would you consider to be the major problems confronting your household?

1. Water supply
2. Good Roads
3. Electricity
4. Schools
5. Health Centre
6. Poverty
7. Household Toilet
8. Others (_____

Water Supply

14. How many water sources do you have in this community?

1. None 2. One-Two 3. Three-Four 4. Five-Six 5. Above Six

15. How many are improved water sources?

1. Improved hand dug well with rope and bucket
2. Improved hand dug well with hand pumps
3. Borehole with hand pump
4. Small town water systems (stand pipes)
5. Rain water harvester
6. Protected spring

16. How many are non-improved water sources?

1. Traditional/unlined dug well 2. Stream 3. River 4. Ponds

Access to Water Sources in Rainy Season

17. Purpose water use

1. Drinking 2. Cooking 3. Washing 4. Bathing 5. Feeding of animals

18. Distance to and from improved water point (meters)

1. Less than 250 meters 2. 250-500 meters 3. 501 meters- 1 Kilometer 4. Above 1 kilometer

19. Time spent to and from water point in rainy season

1. Less than 30 minutes 2. 30 mins- 1hour 3. 1-2 hours 4. Above 2 hours

20. How many litres do your household have access to per day per capita

1. Less than 20 litres 2. 20-35 litres 3. Above 35 litres

21. Reliability during rainy season
1. Reliable 2. Not reliable

Access to Water Sources in Dry Season

22. Purpose of water use
1. Drinking 2. Cooking 3. Washing 4. Bathing 5. Feeding of animals

23.**Distance to and from improved water point (meters)**

1. Less than 250 meters 2. 250-500 meters 3. 501 meters- 1 Kilometres 4. Above 1 Kilometres

24. Time spent to and from water point in dry season

1. Less than 30 minutes 2. 30 mins- 1hour 3. 1-2 hours 4. Above 2 hours

25. How many litres do your households have access to per day per capita

1. Less than 20 litres 2. 20-35 litres 3. Above 35 litres

26. Reliability during rainy season

1. Reliable 2. Not reliable.

Water Facility Management

27. Did you contribute to the construction of the improved water point?
1.Yes 2. No

28. If yes, was it in cash (money) or in kind (labour, materials)?
1. Cash 2. Kind

29. Do you pay for water collected from the improved water point?
1. Yes 2. No. 3. Sometimes

30. Are all the families using water point paying the same fees?
1. Yes 2. No

31. Is there a group of people responsible for taking care of the water point?
1. Yes 2. No 3. Don't Know

32. If yes to above, how many are female?

1. One-Two 2. Three-Four 3. Above Four

33. In your own opinion, have they carried out these duties Effectively?
1. Yes 2. No 3. Don't Know

34. Have you experienced any breakdown of water point in the past one year?

1. Yes 2. No

35. Do you pay for the repairs?

1. Yes 2. No

36. In your view, are you satisfied with the imposed water supply system?

1.Yes 2. No

37. How often does the water point break down?

1. Weekly 2. Monthly 3. Quarterly 4. Yearly

38. How long does it take to get the water pump repaired?

1. Within in a Week 2. Up to a month 3. More than three months 4. More than six months 5. Never

Sanitation Access

40. Do you have your own latrine/toilet?

1. Yes 2. No

41. Where do your household dispose solid waste?

1. Anywhere in the compound
2. In the bush around the compound
3. Packed in a pit and burnt
4. In a community refuse dump
5. Inside the incinerator

Climate Change Issues

42. Are you aware about climate change issues?

1. Yes 2. No

Appendices: E

Perception survey questionnaire

1. Self-supply

What is your perception on the principle of self-supply relevant to HDW in the area on the scale of 1-5 (1 = strongly disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly agree)

Building block for HDW self- supply	1	2	3	4	5
Technical option of HDW					
Access to finance to construct the well					
Private sector engagement to carry out the work					
Enabling government policies on HDW construction					

2. RPT

What is your perception on viability of RPT for private and public self-supply HDW on the scale of 1-5 (1 = strongly disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly agree)

Viability of rope pump technology	1		2		3		4		5	
	Private	Public	Private	Public	Private	Public	Private	Public	Private	Public
Acceptability										
Access to finance										
Private sector engagement										
Enabling government policies										

3. CBWRM

What is your perception on the application of Dublin principles rural water resource management the scale of 1-5. (1 = strongly disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly agree)

Application of Dublin principles towards CBWRM	Strongly agree	Agree	Uncertain	Disagree	Strongly Disagree
Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.					
Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.					
Women play a central part in the provision, management and safeguarding of water.					
Water has an economic value in all its competing uses and should be recognised as an economic good.					

Please be assured that your confidentiality and anonymity are guaranteed.
All information collected will conform to the University's Human Research Ethical procedure.

Appendices: F

Validation survey questionnaire

Name…… …….
Organisation……
Designation ……
Date …….

What is your perception on the SRUWASSD guidance framework developed? Please express your opinion on the relevance and applicability of the proposed framework on the scale of 1- 5 (where 1 least relevant and 5 most) relevant)

Sustainability factor	Financial	Institutional	Environmental	Social	Technical
Relevance and applicability					

Please provide comments and recommendation:

Please provide constructive criticism:

Please be assured that your confidentiality and anonymity are guaranteed.
All information collected will conform to the University's Human Research Ethical procedure.